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Population status of the Illinois chorus frog
(*Pseudacris streckeri illinoensis*)
in Madison County, Illinois: Results of 1994 surveys

IDOT CONTRACT 1-5-90179

FINAL REPORT ON 1994 RESULTS

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DISCLAIMER

The findings, conclusions, and views expressed herein are those of the researchers and should not be considered as the official position of the Illinois Department of Transportation.

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EXECUTIVE SUMMARY

A study of the biology of the Illinois chorus frog, *Pseudacris streckeri illinoensis*, is reported. Surveys of Madison County for choruses of the frogs located seven choruses. Choruses previously reported at Granite City and South Roxana were not relocated and are thought to be extirpated. We estimated population size to be 420 frogs in April 1994 with a juvenile survivorship of 4.5%. Mean distance for 20 recaptured frogs from point of initial capture was 0.52 km with a range of 0 to 0.9 km. Habitat preference for 48 frogs found on roads appeared to be for old field habitats in preference to areas of agriculture or lawns. We believe that the current distribution of *P. s. illinoensis* on the Poag sand terrace can be best explained by assuming that agricultural practices exclude the frog through increased juvenile mortality. We found this frog preyed heavily on lepidopteran larvae. Caterpillars of the dingy cutworm (*Feltia ducens*) made up 45.8% of the food items and 84.5% of the mass of items found in 17 frogs. We found 608.2 oviductal eggs per frog among five females. Individual egg masses averaged 21.9 eggs per mass. Growth was rapid with froglets averaging 1.18 mm/day in growth. At least some froglets matured in a single year. We found frogs most active during rain events and during the middle hours of the night. Frogs did not use a former chorus site due to fish being introduced to it. We also found significant reproductive failure in ephemeral ponds that resulted from slow drainage in areas of human habitation. Eggs deposited in these sites failed to develop due to habitat drying. We estimate that habitat drying may have resulted in reproductive failure for as much as 11% of the females breeding in 1994.

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ACKNOWLEDGMENTS

We thank S. R. Ballard, J. B. Camerer, J. B. Hatcher, G. B. Rose, and M. M. Tucker for field assistance. R. Maher and F. Cronin confirmed identifications of fishes. R. Weinzierl identified the cutworm caterpillars. L. E. Brown provided many useful suggestions concerning the biology of the frog and helped with literature needs. G. B. Rose pointed out locations of historical records for choruses. G. E. Kruse provided permits necessary for this project. K. Brockmeier, Brockmeier Sod Farms, allowed unrestricted access to his property and permitted drift fences to be placed in his wheat field. The staff at Home Greenhouses allowed us access to their facilities.

INTRODUCTION

The Illinois chorus frog, *Pseudacris streckeri illinoensis*, is restricted to areas of sandy substrates found in the floodplains of the Mississippi and Illinois rivers in Arkansas, Illinois, and Missouri (Conant and Collins, 1991). Because these habitats have been converted to agriculture or developed for other human activities, *P. s. illinoensis* is now uncommon. It is listed as a threatened species in Illinois (Herkert, 1992).

This highly fossorial frog is distributed in Illinois mainly along the central part of the Illinois River (Smith, 1951, 1961, 1966; Morris and Smith, 1981; Taubert, *et al.*, 1982; Brown and Rose, 1988; Morris, 1990; Beltz, 1991 and 1993). Other populations are, also, scattered along the Mississippi River floodplain from Madison to Alexander Counties, Illinois (Holman, *et al.*, 1964; Brown and Brown, 1973; Axtell and Haskell, 1977; Morris and Smith, 1981; Taubert, *et al.*, 1982; Gilbert, 1986; Brown and Rose, 1988; Morris, 1990; Beltz, 1991 and 1993; Tucker and Philipp, 1993).

Several previous publications and unpublished reports provide details on the life history of *P. s. illinoensis* including information on underground feeding behavior (Brown, 1978), burrowing behavior (Axtell and Haskell, 1977; Brown et al., 1972; Tucker et al., 1995; Tucker, 1995), chorus sites (Brown and Rose, 1988), fecundity (Butterfield et al., 1989), post-metamorphic growth (Tucker, 1995), and morphological adaptations to fossorial existence (Paukstis and Brown, 1987; 1991).

The present report is a summary of results for 1994 and a continuation of studies that we initiated in 1993 (Tucker and Philipp, 1993). Our initial objectives were:

1. Determine the distribution of *P. s. illinoensis* choruses in appropriate habitat in the impact area.
2. Determine the approximate number of breeding individuals visiting choruses that are located in the impact area.
3. Evaluate suitability of three possible alternate wetland mitigation sites as potential *P. s. illinoensis* habitat.

4. Develop a management strategy for whichever of the three possible sites that are consistent with continued habitation of the frog at the site.

Objective 3 was the subject of a previous report (appendix 1) and is not further considered in the text of the current report. Objective 4 cannot be completed until final procurement of a specific mitigation site and will be addressed later. However, we can report important results concerning objectives 1 and 2.

As a result of observations made in 1994, we develop a model to account for the current distribution of the frog in Madison County. This model incorporates information on post-metamorphic movements and habitat preferences developed during 1994 observations. We call this model, extinction by attrition, and it is included as a separate section of the report. We also report on other aspects of the natural history of the frog. These include food habits, fecundity, post-metamorphic growth, activity patterns, and anthropogenic effects on breeding success . We discuss these in a separate section of the report: Natural History Observations.

OBJECTIVE 1: DISTRIBUTION OF *PSEUDACRIS STRECKERI ILLINOENSIS*

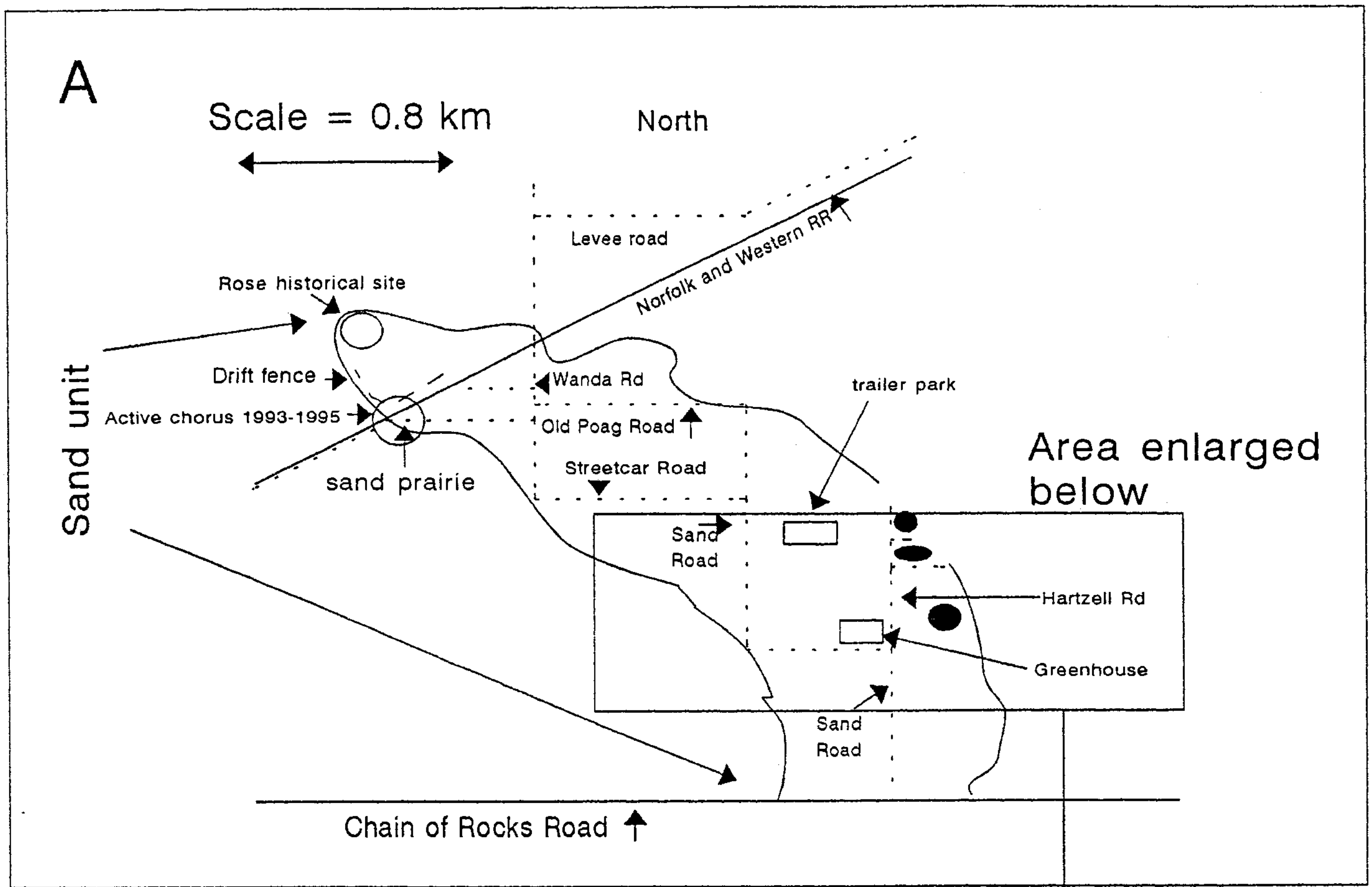
METHODS: Starting 1 March 1994, we patrolled roads at night particularly on nights when rain fell or had fallen in the last 24 hours. Periodically, we stopped to listen for chorusing frogs. When *P. s. illinoensis* was heard at a stop, identification was considered tentative if the frog or frogs could not be caught and confirmed if frogs were captured.

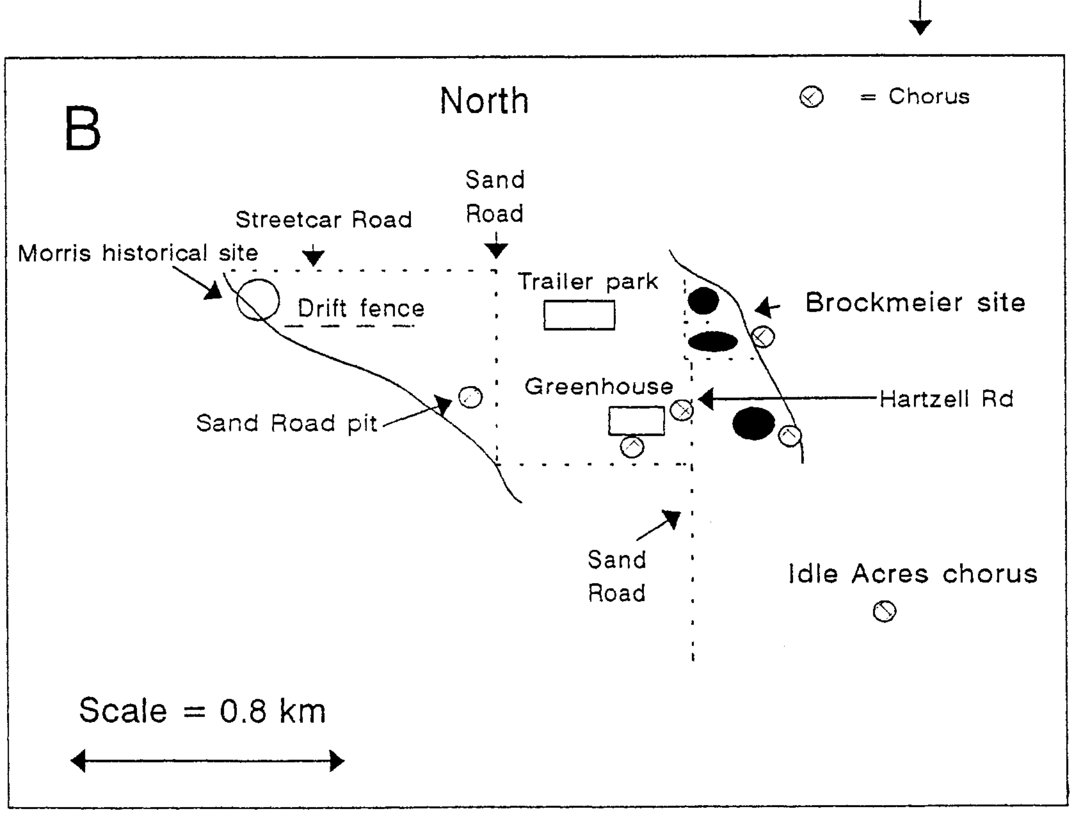
The area investigated by road surveys is contained in the polygon defined by Interstate 270 to the south, Ill. route 157 to the east, Ill. route 3 to the west and Ill route 143 to the north. This area was selected because it contains all of the historical published and verbally reported (to George Rose or Michael Morris) chorus locations in the vicinity of the route of FAP 310.

RESULTS: In 1994, a total of seven choruses were located (Fig. 1). At five of these, we confirmed the identity of the calling frogs by catching one or more specimens of *P. s. illinoensis* (Fig. 1B, excluding Idle Acres chorus).

Figure 1. A.-The Poag sand terrace showing the relationship of the study area containing the last confirmed population of *Pseudacris streckeri illinoensis*. B.-The Sand Road study area showing locations of six of the seven chorus sites active between 1993 and 1995.

Figure 1


A
Scale = 0.8 km
North
Levee road
Norfolk and Western RR
Rose historical site
Sand unit
Drift fence
Active chorus 1993-1995
sand prairie
Wanda Rd
Old Poag Road
Streetcar Road
trailer park
Area enlarged below
Sand Road
Hartzell Rd
Greenhouse
Sand Road
Chain of Rocks Road


B
North
= Chorus
Sand Road
Streetcar Road
Morris historical site
Trailer park
Drift fence
Brockmeier site
Greenhouse
Hartzell Rd
Sand Road pit
Sand Road
Idle Acres chorus
Scale = 0.8 km

DISCUSSION: Axtell and Haskell (1977) reported that *Pseudacris streckeri illinoensis* is widely distributed in the "Cahokia crescent". They reported locating five separate populations in a 15 km^2 area. They took especial note of a site near Granite City. Taubert et al. (1982) could locate only three breeding sites in Madison County including the Granite City site reported by Axtell and Haskell (1977). The sites that they reported included those located at Sec. 8, T3N, R9W (= Axtell and Haskell's site), Sec. 18, T4N, R8W, and Sec. 19, T4N, R8W (latter two = Brockmeier site, herein). Morris (1992) reported the Sand Road pit site mentioned here.

Choruses of *P. s. illinoensis* were found at only two locations during 1993, a year in which surveying began long after the frogs had begun to breed (Tucker and Philipp, 1993). Even though we found more choruses active than in previous surveys (i.e., Taubert et al., 1982; Tucker and Philipp, 1993), this does not mean that the frogs are increasing in numbers. In fact, with the possible exception of the Sand Prairie site (Fig. 1A), all of the choruses that we located are in close geographical proximity to each other, and basically are contained in the equivalent of about 1/3 of a section. Likely, all of the frogs belong to the same breeding population (see below).

We were not able to locate frogs at the Granite City site reported by Axtell and Haskell (1977) even though we searched it in 1994 when frogs were calling elsewhere. It is possible that the extensive urbanization at the Granite City site has extirpated the frog there. If so, then only one population remains in Madison County.

A number of undocumented records for the South Roxana area are mentioned by Morris (1992). These are located on a different sand unit (see below) than the one where frogs are known to exist. We surveyed these location numerous times during 1994 and found no choruses of *P. s. illinoensis* at times when frogs were calling elsewhere. The Roxana choruses seem to have been extirpated.

OBJECTIVE 2: ESTIMATION OF POPULATION SIZE

METHODS: Theoretically, it is possible to come to preliminary estimates of population sizes based on recaptures in 1994 of the frogs marked in 1993 using the Lincoln index method. Although we present these estimates here, much caution is advised in their acceptance (see McArdle et al., 1990 and Nunney and Elam, 1994, for cautions on reliance on such preliminary estimates).

Population estimates basically require that all frogs have an equal chance to be recaptured and this is unlikely in this case. Our determination assumes that frogs did not leave the study area during their post-metamorphic migration, an assumption not true for other frogs (i.e., Berven and Grudzien, 1990). As a consequence, the number of frogs marked in 1993 must be adjusted to reflect the estimated number of frogs remaining to be recaptured after the effect of juvenile mortality is taken into consideration. Therefore juvenile survivorship must be known to estimate adult population size from data based originally on froglets leaving the natal pond.

In 1993, we marked 722 froglets (735 less 13 vouchers). Based on the number of froglets marked leaving the pond (252), those recaptured (104) at the field fences, and 483 unmarked frogs caught at field fences, we estimate that 1170 froglets transformed at the south pond at the Brockmeier site (Tucker and Philipp, 1993). Of the froglets that left the pond, 722 of 1170 (61.7%) were marked by us. Recaptures of frogs marked as froglets returning to breed yielded a preliminary estimate of juvenile survivorship (i.e., survivorship to sexual maturity) once corrected for the percentage of frogs marked. We determine juvenile survivorship by dividing the number of frogs recaptured by the number of froglets marked. This result is then divided by the proportion of froglets marked among all froglets leaving the natal pond (i.e., the method of Smith, 1987).

RESULTS: In 1994, we recaptured 20 of 722 frogs. Assuming that 61.7% of the transforming froglets were marked initially, then the estimated juvenile survivorship was 4.5%. However, if significant numbers of frogs do not mature until their second year, this estimate will be low.

Estimating population size is complicated by the fact that 1170 froglets (722 of them marked) entered the population in May, 1993. However, if the estimated juvenile survival rate (above) is close to the actual one, only 53 frogs would remain available to be recaptured in April 1994. The marked set then is estimated to be 53 one year old frogs + three adult males marked in 1993. Of these, 20 were recaptured among the 150 frogs caught in 1994. Using the ratio: population size/56 marked frogs = 150 frogs caught 1994/20 recaptured frogs 1994 yields a population estimate of 420 frogs.

DISCUSSION: Nothing is known of the demographics of this subspecies. The estimate of juvenile survivorship of 4.5% is the first estimate of survivorship for this subspecies. Our estimate of juvenile survivorship would be low if froglets that transformed elsewhere dispersed into the area where the recaptures were made. Consequently, our preliminary estimate of juvenile survival rate should be viewed as a minimum one.

This preliminary estimate of juvenile survivorship for *Pseudacris s. illinoensis* is lower than the range of juvenile survivorship reported by Smith (1987: 10.0-6.4%) for *P. triseriata*. Smith's (1987) study site was in the protected and little disturbed Isle Royale National Park which is a far cry from the highly disturbed environment that *P. s. illinoensis* contend with in Madison County. Both *P. s. illinoensis* and *P. triseriata* had much lower juvenile survivorship than the 37.9% observed for *Rana sylvatica* by Berven (1990).

The estimate that about 420 frogs make up the Madison County population while preliminary suggests that the population is vulnerable to extinction. Any human activity or natural event that interferes with reproduction could be disastrous. Vulnerability is further increased due to low juvenile survivorship that we estimated.

EXTINCTION BY ATTRITION

METHODS: We estimated post-metamorphic movements by plotting distances between point of recapture and point of initial capture for 20 recaptured frogs marked by us in 1993 as froglets (Tucker and Philipp, 1993).

Direction of travel when first observed, the precise location of the frog, and the habitats being entered and left were recorded for 48 AOR frogs.

Habitats were scored as old-field, agriculture, or lawn. For each frog, we recorded the exact location of capture on the road on maps photocopied onto water proof paper.

Gravid females were presumed to be moving from nonbreeding habitat to choruses, whereas spent females were presumed to be returning from breeding choruses to nonbreeding habitats. Since choruses began 10 April and remained at a high level through 16 April with sporadic activity after that until 28 April, male frogs could be moving to or from choruses. Those caught between 9 April and 18 April were arbitrarily considered to be moving to choruses whereas those caught after that date were considered to be moving back to nonbreeding habitat. Habitat preference was not scored for frogs caught at choruses.

We then scored nonbreeding habitat preference using the assumption that gravid females and males collected between 9 and 18 April were leaving their nonbreeding habitat. For these frogs, nonbreeding habitat was scored based on the nature of the habitat left rather than the habitat entered. We also scored nonbreeding habitat preference using the assumption that spent females and males collected after 18 April were returning to their nonbreeding habitat. Consequently, nonbreeding habitat for this cohort of the frogs observed was scored based on the nature of the habitat entered rather than the habitat left (Figs. 2 and 3).

RESULTS: Mean distance from the natal pond (= south pond at the Brockmeier site-Fig. 1B) to the site of recapture for the 20 frogs recaptured in 1994 was 0.52 km (range = 0-0.9 km, SD = 0.23 km). The females were recaptured an average of 0.59 km from the natal pond (range = 0.46-0.9 km, SD = 0.18 km), whereas males were recaptured an average of 0.49 km (range = 0-0.71 km, SD = 0.25 km) from the natal pond. The distance from point of recapture to the point of initial capture for males and females did not differ statistically (kw = 0.54, p = 0.4605, df = 1).

Not only did frogs move significant distances but they did not appear to show site fidelity in their first breeding attempt. Three of 13 males and

Figure 2. Location of AOR frogs in relation to ground cover in April 1994.

Figure 2

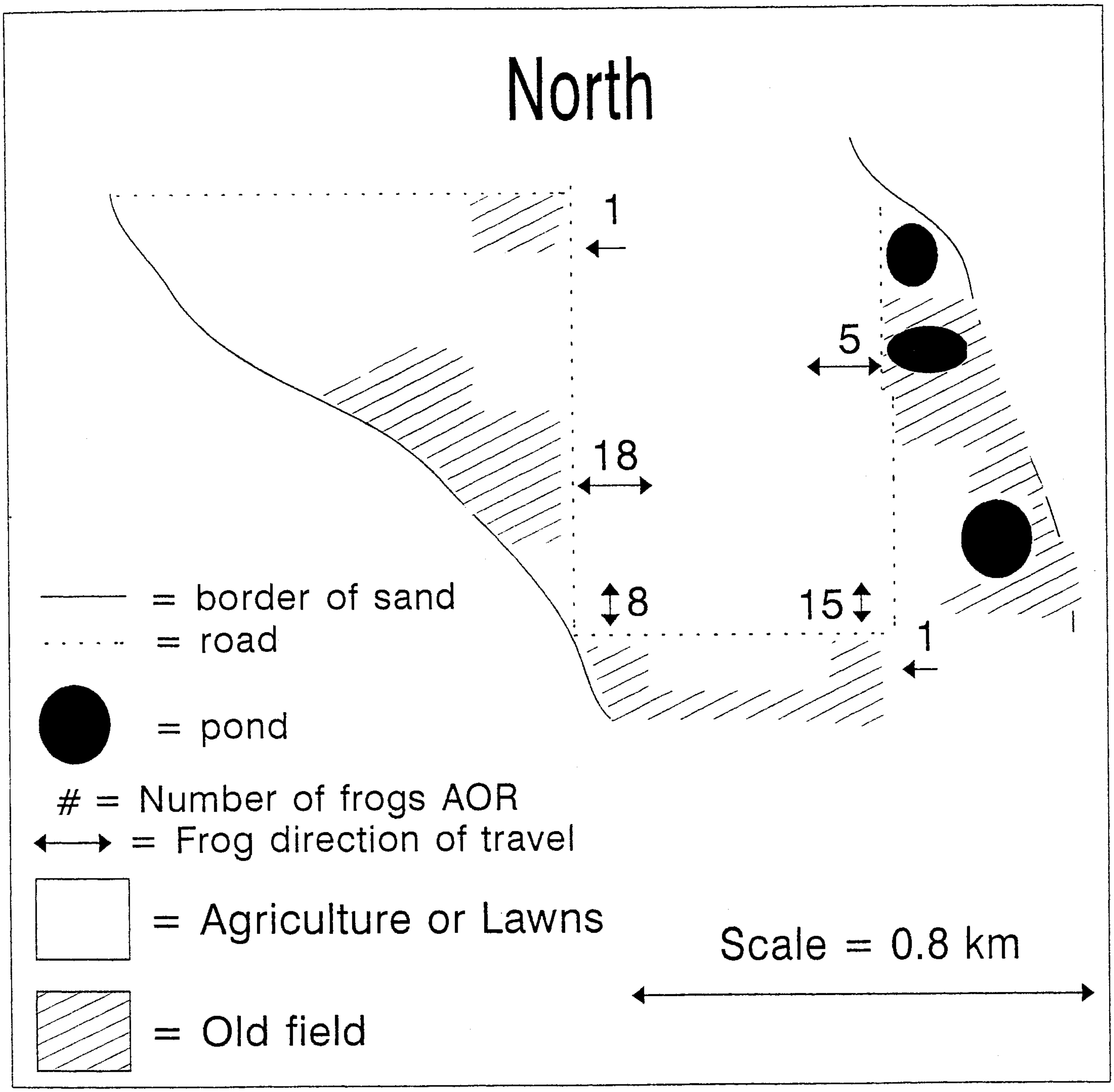
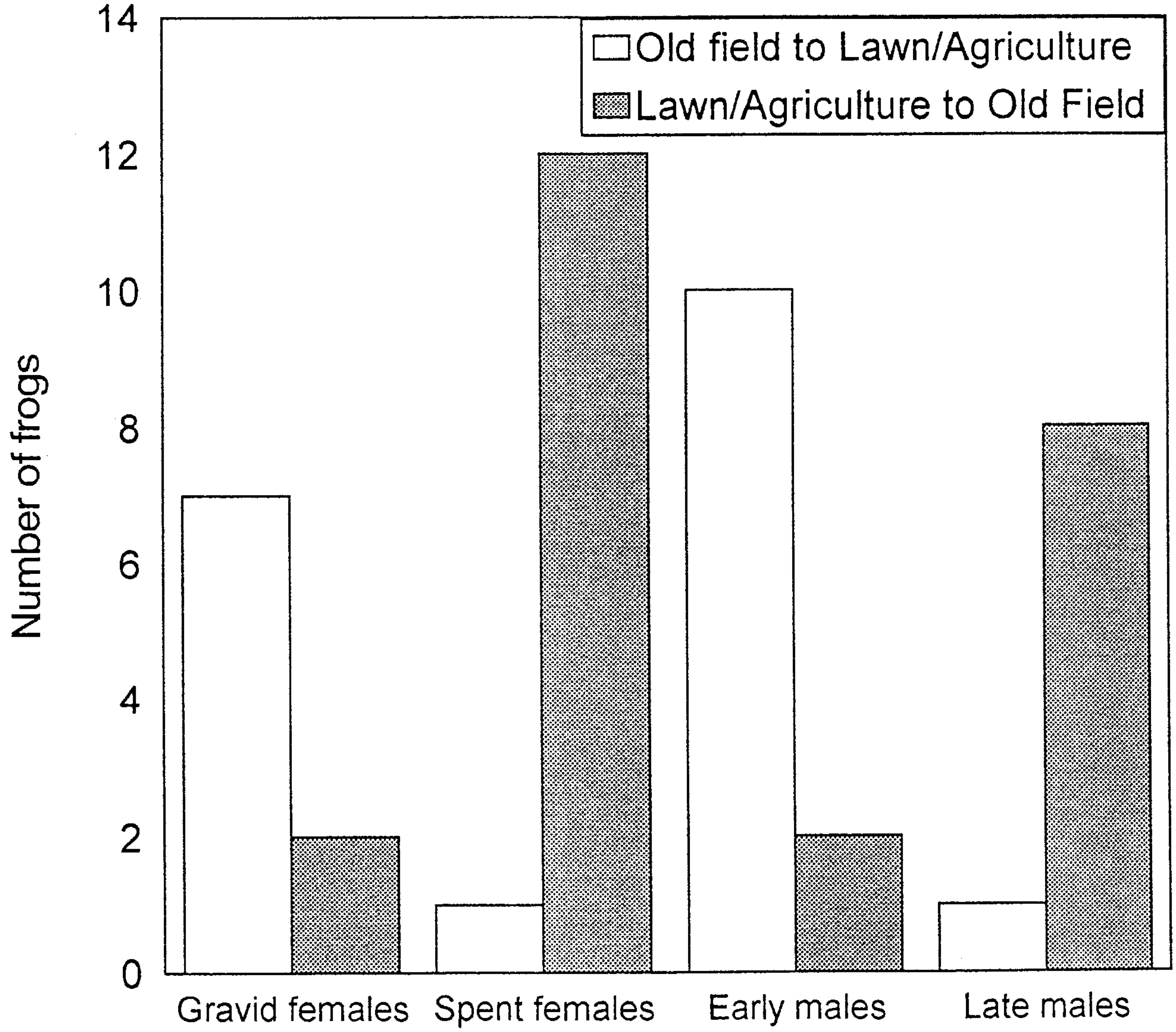

North
1
5
18
8
15
1
= border of sand
= road
= pond
= Number of frogs AOR
= Frog direction of travel
= Agriculture or Lawns
= Old field
Scale = 0.8 km

Figure 3. Direction of travel for 48 AOR frogs in 1994 in relation to ground cover.

Figure 3



14
12
10
8
6
4
2
0
Number of frogs
Old field to Lawn/Agriculture
Lawn/Agriculture to Old Field
Gravid females
Spent females
Early males
Late males

three of seven females that emigrated from the south pond as froglets were recaptured at the Sand Road pit chorus. Two of the males were found at the greenhouse chorus. The remaining frogs were found on roads with the exception of one male recaptured on drift fences at the south pond.

Frogs found on roads in this study were not randomly distributed along the road path (Fig. 2). Areas of concentration were associated with areas of old field habitat on one side or the other of the road. Frogs were not found in areas where agriculture or lawns bordered both sides of the road (Fig. 2). The direction of travel (Fig. 3) changed abruptly in the study as well.

During the first part of the breeding season most gravid females and early males were found leaving old field habitats (i.e, 17 of 20). In the late part of the season, most spent females and late males were found entering old field habitat (i.e., 20 of 22). The concentration of frog captures at areas of the road where old field habitat occurred (Fig. 2) along with the direction of travel strongly suggested that frogs preferred such habitats as compared to agriculture or lawns.

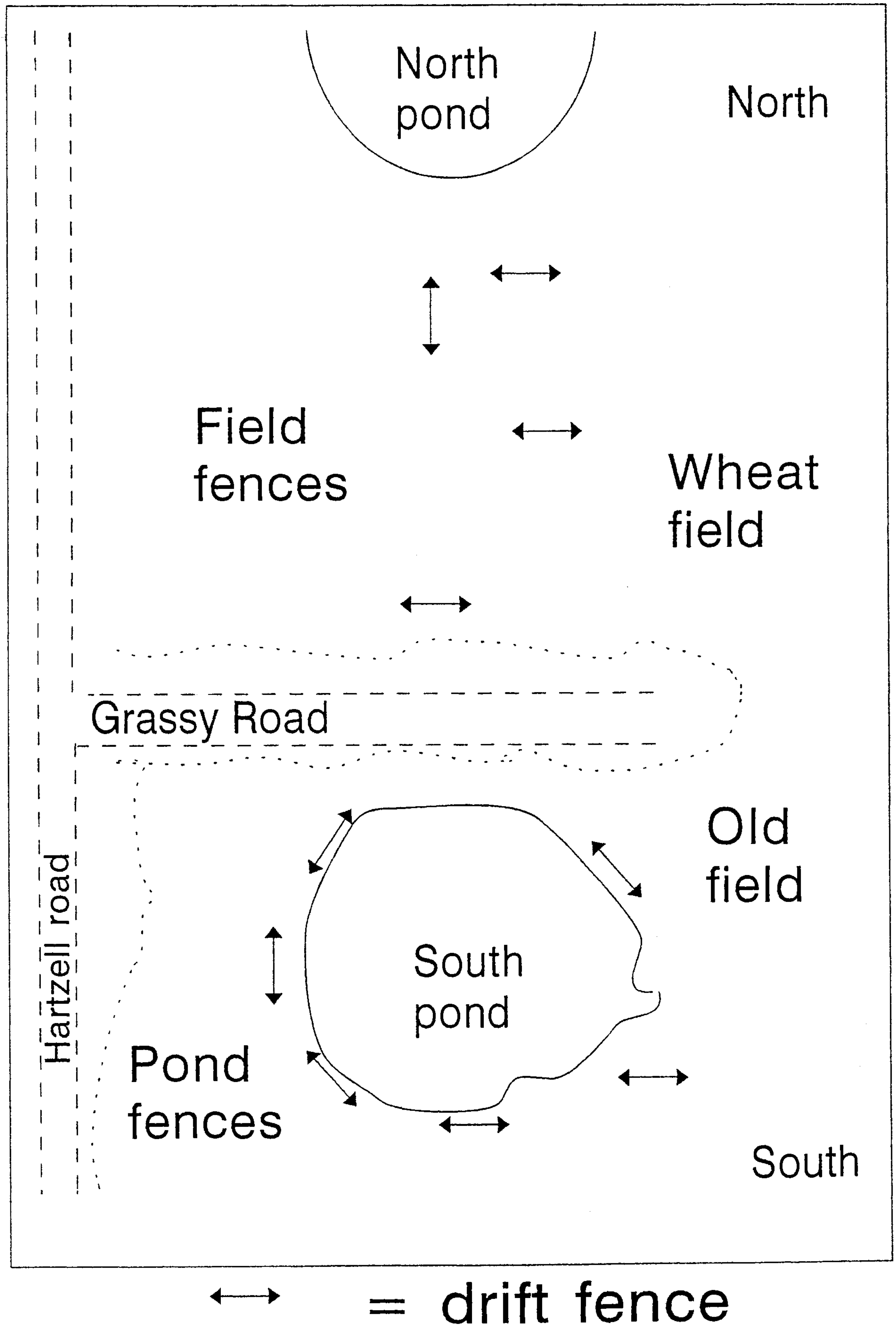
DISCUSSION: Tucker and Philipp (1993) using drift fences positioned along the path that froglets were expected to take estimated how long it takes for froglets to get from one set of fences to the next. In 1993, froglets took 46.4 h to traverse the mean distance (70 m) between fences at the pond's edge and fences placed in the adjoining wheat field at the Brockmeier location (Fig. 4, Tucker, 1995). This yielded a travel rate of 1.5 m/h for these froglets.

At this rate, the froglets could travel significant distances in relatively short periods of time. For instance, it would take 14 days for a froglet to traverse 500 m at this rate, if it traveled continuously (Tucker and Philipp, 1993). The locations of frogs marked as froglets in 1993 and recaptured in 1994 indicate that they do move considerable distances for a fossorial frog.

It is well known that choruses are frequently located in habitats not suitable for the fossorial life style of this frog when it is not breeding

Figure 4. Drift fence placement used to collect transforming froglets in 1993 at the Brockmeier south pond.

Figure 4


North pond
North
Field fences
Wheat field
Grassy Road
Old field
Hartzell road
South pond
Pond fences
South
= drift fence

(see Brown and Rose, 1988). This is a result of the generally well drained nature of the sand habitats of the frogs.

Throughout this study, one of our concerns was why this species is not more widely distributed in the area. Suitable looking habitat containing the sand substrates needed by the frog for nonbreeding habitat is fairly widespread in the general area where the last remaining population is located. In fact, another large sand terrace is located less than 0.3 km immediately to the north of the terrace shown in Fig. 1A. Not only do frogs not occur on that terrace, they do not even occupy the entire extent of the terrace where the study area is located. Except for the chorus at the sand prairie, we found no frogs north of Streetcar Road.

The microgeographic distribution pattern of the frogs on this sand unit suggests that the lack of movement corridors (i.e., Simberloff et al., 1992), the absence of habitat connectivity (i.e., Fahrig and Merriam, 1985), and possibly site fidelity (Blaustein et al., 1994) impedes recolonization in areas of otherwise suitable nonbreeding habitat where the frogs have become locally extinct. Thus frogs remain absent at the Rose and Morris historical sites despite the relatively close proximity of other choruses which produced froglets, potential colonizers.

The possible effect of agriculture on *P. s. illinoensis* is not widely appreciated because most surveys consider where frogs are calling and not where they came from to call or where they will go when the breeding season stops. As noted above the frog will enter agricultural areas when it is moving to breeding choruses and when it is moving away from the natal pond. Our hypothesis is that though juvenile frogs may enter and occupy agricultural areas, they do not survive the experience. We suggest that the distribution of adults in 1994 and the fact that nearly all AOR recaptures were leaving or returning to oldfield habitats is consistent with that hypothesis but does not test it.

Several assumptions are inherently necessary. First, we assume that the frogs have a home range as do other anurans though we cannot see this particular frog while they are in it. We also assume that when warm spring rains trigger emergence for breeding that the frogs leave their home range and find suitable breeding sites (i.e., fishless bodies of water). We make an important assumption that once breeding is completed that they return to their home ranges.

These assumptions while untested for *P. s. illinoensis* are not unreasonable. In an elegant study, Clarke (1974) fond that adult *Bufo woodhousii fowleri*, another species with well developed fossorial behavior, maintained home ranges. He further noted (Clarke, 1974, p. 269) that "Many individuals are known to have used the same home range for 2 or 3 years and some were found at the breeding pond up to 312 m away, with subsequent captures on the established home range."

Our hypothesis that young-of-the-year frogs cannot persist in areas of agriculture is testable by tracking the fate of froglets that settle in such areas assuming some do. Such a test would not be an easy task to conduct in the field for this species. Laboratory experiments exposing young (or old) frogs to substrates recently treated with the sorts of soil insecticides and other chemicals commonly used in agriculture could also provide interesting results and an indirect test of the hypothesis. The effects of mechanical disturbance caused by agricultural equipment on the frog would be more difficult to examine. Examination of pesticide residues in adults and froglets would likewise be important. Given that underground feeding in nature is important, surveys of soil invertebrate faunas in relation to agricultural practices would be valuable.

Whatever the cause of the apparent absence of recolonization of areas where the frog once lived, it suggests a pattern of extinction that we call extinction by attrition. Prior to disturbance (Fig. 5A), we assume that this sand terrace and likely others nearby had frogs widely distributed on them. Frogs bred along the edges of the terrace where soil types allowed water to stand as well as on the terrace in spots where the sand did not drain too rapidly. The froglets produced dispersed over the terrace. In their first

Figure 5. A.-Initial undisturbed habitat. B.-Insertion of an area of disturbed habitat into which froglets disperse but do not survive. C.-Result at some time after disturbance. Chorus in the most isolated and smallest habitat patch is lost. D.-After a longer time, choruses at other isolated but larger patches are lost due to absence of juvenile recruitment into choruses.

Page 19 missing from the bound original

year, they moved to chorus sites but not necessarily to the ones where they were produced. However, we assume that survivors of these one year olds would be more likely to return to the site they breed at first (i.e., they develop site fidelity after the first breeding experience).

Then an environmental disturbance such as the initiation of agricultural practices makes a portion of the former nonbreeding range unsurvivable for froglets (Fig. 5B). Since froglets cannot predict this from outward appearances, they continue to disperse into the area after each breeding season. Those settling in the disturbed area do not live to reproduce. Juvenile recruitment as a result is reduced. Experienced frogs whose home ranges did not include the new condition continue to disperse to the breeding chorus that they bred in their first breeding season. However, they are joined only by froglets that did not come to inhabit the unfavorable habitat. Thus, the recruitment into the chorus is reduced.

If the disturbance is not widespread, the chorus will be maintained by the froglets that happened to settle in remaining suitable habitat and end up at the chorus site on their first breeding trip. Once the disturbance is sufficiently widespread to reduce juvenile survivorship below the rate necessary to compensate for annual adult mortality, then the chorus will dwindle and go extinct (Figs. 5C, D).

This pattern of extinction is not new and has been discussed previously in relation to habitat patch connectivity (i.e., Fahrig and Merriam, 1985). However, in the model that we propose, we do not suggest that the froglets do not enter the unsuitable habitat but that those that do are lost or at least fair poorly as compared to those that do not.

The similarity between the hypothetical scenario and the actual situation in Madison County is striking. The Morris and Rose historical sites are equivalent to the choruses that have gone extinct. They are isolated from active choruses by significant areas of unsuitable habitats, yet the habitat in the area where choruses were reported appear suitable (i.e., they are old field habitats). The sand prairie site may represent a chorus in the process of extinction. It too is isolated from other choruses.

Only the choruses at the Sand Road pit site and the Brockmeier site appear to be stable. However, this has not been established with certainty (i.e., Connell and Sousa, 1983). First, we have no estimate of larval or adult survivorship. Second, the estimates of population size and juvenile survivorship are preliminary. We treat them as values but such life-history traits are really averages of year-to-year conditions (Dennis et al., 1991). Without continued study, we cannot determine whether the estimates are on the high side, on the low side, or in the middle of the range of variation.

Throughout this report we have not commented on conservation and management for this frog. However, the basic life history parameters reported by us indicate that preservation of significant tracts of suitable habitat for froglets to disperse into is critical. Exactly how this habitat should be managed is not clear and cannot be addressed by our study because only highly altered habitats occur remain in the study area.

NATURAL HISTORY OBSERVATIONS

Food habits

METHODS: We examined the contents of stomachs from 23 road-killed specimens of *P. s. illinoensis* collected between 11 and 15 April 1994. These frogs were killed as they moved to breeding choruses. Of these 23, six specimens did not have intact stomachs, and were excluded from the study. At the same time in 1994, we collected 39 specimens of *P. t. triseriata* for comparison. These frogs were found as they were crossing roads or were caught at drift fences (Fig. 1B). We did not use specimens collected at choruses because they might not be comparable to specimens of *P. s. illinoensis* which were killed while moving to choruses. For both, we weighed each food item (to 0.0001 g) on a Sartorius electronic balance. Insects were identified to the lowest possible taxon (Borror et al., 1989).

RESULTS: We found the stomach contents (Table 1) of *P. s. illinoensis* dominated by the larva of the dingy cutworm, *Feltia ducens*, both in number of items (45.8%) and by mass (84.5%). Of the 17 frogs with intact stomachs,

Table 1. Comparison of food items and mass of items found in the stomachs of 17 specimens of *Pseudacris streckeri illinoensis* and 39 specimens of *Pseudacris triseriata* from Madison County, Illinois.

Pseudacris streckeri illinoensis

	N	% of all items	mass (g)	% of mass	Number of frogs with item	% of all frogs
Arachnid..................	3	6.4	0.0169	0.7	3	17.6
Hemiptera						
Gerridae..................	4	8.3	0.0520	2.1	4	23.5
Coleoptera						
Curculionoidea............	4	8.3	0.0674	2.8	4	23.5
Other beetles.............	4	8.3	0.0677	2.8	4	23.5
Diptera-adult.............	5	10.4	0.0623	2.5	4	23.5
Lepidoptera-larvae........	22	45.8	2.0732	84.5	11	64.7
Hymenoptera						
Formicidae...............	1	2.1	0.0087	0.4	1	5.9
Apoidea..................	1	2.1	0.0417	1.7	1	5.9
Unidentified insect parts..	4	8.3	0.0625	2.5	4	23.5
No identifiable food					1	5.2
Total................	48	100	2.4524	100		

Pseudacris triseriata

	N	% of all items	mass (g)	% of mass	Number of frogs with item	% of all frogs
Oligochaete...............	1	3.0	0.0175	5.9	1	2.6
Arachnid..................	6	18.2	0.0314	10.7	6	15.4
Hemiptera						
Gerridae..................	2	6.1	0.0018	0.6	2	5.1
Coleoptera						
Curculionoidea............	3	9.1	0.0084	2.9	3	7.7
Other beetles.............	7	21.2	0.0126	4.3	4	10.3
Diptera						
Adult....................	2	6.1	0.0033	1.1	2	5.1
Larva....................	1	3.0	0.0265	9.0	1	2.6
Lepidoptera-larvae.........	1	3.0	0.1548	52.5	1	2.6
Hymenoptera-Formicidae.....	5	15.2	0.0126	4.3	5	12.8
Unidentified insect parts..	5	15.2	0.0214	7.3	5	12.8
No identifiable food					20	51.3
Total................	22	100	0.2948	100		

64.7% had eaten this species of cutworm. This cutworm overwinters as a partially mature larva (Weinzierl pers. comm.). The species was common in the area, and we frequently noted it at drift fences used during our study. The cutworm was found in the gut of a single *Pseudacris triseriata* (Table 1). While it made up only 3% of the items found, it accounted for 52.5% of the mass of all food items that we found in *P. triseriata*.

Males and females of *P. s. illinoensis* did not differ in the average number of items (Kruskal-Wallis test (= kw henceforth); kw = 0.01, p = 0.9072, degrees of freedom (= df henceforth) = 1) that they consumed nor in the average mass (kw = 0.39, p = 0.5332, df = 1) of the items in each stomach.

In contrast, males of *P. triseriata* consumed fewer food items than female *P. triseriata* (kw = 7.76, p = 0.0053, df = 1). Furthermore, the food items found in male *P. triseriata* weighed less (kw = 7.85, p = 0.0051, df = 1) than those found in female *P. triseriata*. We used analysis of covariance (= ANCOVA henceforth) to remove the effect of body size (females were bigger than males). The resulting least square means (= LSM henceforth) for items (LSM = 1.19 items/female vs. LSM = 0.72 items/male) did not differ statistically (F = 0.80, p = 0.3783, df = 1, 38). The comparison for mass of the items consumed by males (LSM = 0.0006 g) and females (LSM = 0.0253 g) is statistically significant (F = 5.74, p = 0.0219, df = 1, 38) indicating that female *P. triseriata* contained heaver food items than conspecific males even after correcting for body size differences.

For, *P. s. illinoensis* only one male had an empty stomach. For the *P. triseriata* that we studied, 13 of 28 males and 7 of 11 females did not contain food items. The proportion of male *P. triseriata* with empty stomachs did not differ significantly from those of female *P. triseriata* with food items in the stomach (G test (= G henceforth) G = 0.28, p = 0.5967, df = 1). However, significantly more of all *P. triseriata* had empty stomachs as compared to all *P. s. illinoensis* (G = 6.95, p = 0.0084, df = 1).

Not only do these two frogs differ in the relative number of individuals containing food items but they also differ in the number of items (kw = 6.19,

$p = 0.0128$, df = 1) and in the mass of the items (kw = 18.54, $p = 0.0001$, df = 1). *P. s. illinoensis* consumed more items (mean = 3.0 items, range = 1-9 items, SD = 2.0 items, n = 16 frogs with food items) that were more massive (mean = 0.1531 g, range = 0.0032-0.4539 g, SD = 0.1269 g) than did *P. triseriata* (items: mean = 1.74 items, range = 1-6 items, SD = 1.28 items; mass: mean = 0.0156 g, range = 0.0009-0.1576 g, SD = 0.0355, n = 19 frogs with food items).

If the significant differences in size between the two frogs is taken into account by using ANCOVA, then neither the number of items ($F = 0.29$, $p = 0.5945$, df = 1, 34) nor the mass ($F = 3.32$, $p = 0.0780$, df = 1, 34) differ significantly. The absence of significant interspecific differences suggested that food consumption differences in unadjusted means for mass and items between the two frogs was due to body size differences.

However, the covariate (SVL) is not significant in either analysis ($p > 0.05$). Least square means for *P. s. illinoensis* are 1.90 items weighing 0.1577 g, whereas for *P. triseriata* they are 2.66 items weighing 0.0117 g. Even though the two species do not differ statistically in the small sample (error accounted for 27.3% of the variance in items and 23.0% of the variance in mass) available, the average total adjusted food mass (= LSM items*LSM mass) contained by *P. s. illinoensis* is 0.2996 g, whereas it is only 0.0311 g for *P. triseriata*, nearly a ten-fold difference even after removing effects due to body size.

DISCUSSION: Brown (1978) discovered that *Pseudacris streckeri illinoensis* is able to feed underground, a unique aspect of the biology of this frog. In fact, Brown and his colleagues have demonstrated a unique suite of morphological traits associated with forward burrowing and possibly with subterranean feeding (e.g., Brown et al., 1972; Brown and Means, 1984; Paukstis and Brown, 1987 and 1991). Even so, nothing has been reported on the food habits of *P. s. illinoensis* in nature.

Whitaker (1971) made an extensive survey of the biology of *P. triseriata* in Vigo County, Indiana including the food habits of the species at various stages in its life history. We found that *P. s. illinoensis* and *P. triseriata* both feed during the breeding season at our study area just as Whitaker (1971) reported for *P. triseriata* from Indiana. Sample sizes are small in our study, but the results suggest that *P. s. illinoensis* is a more active feeder during this stage of its life history than is *P. triseriata*.

The concentration on the dingy cutworm may indicate that this lepidopteran was widely available at the time the frogs were moving to breeding choruses rather than a dietary specialization. Whitaker (1971) also noted the importance of lepidopteran larvae (species not specified) in the much more extensive survey of food habits for *P. triseriata* that he conducted. During the breeding season, Whitaker (1971) found that lepidopteran larvae made up 10.5% of the items and 6.0% of the volume of the prey items taken by males and 24.1% of the items and 17.4% of the volume for females. For the latter, lepidopteran larvae were both the most numerous food item and accounted for the most volume as compared to 65 other classes of food items (Whitaker, 1971). Other small hylid frogs (i.e., Johnson and Christiansen, 1976, for *Acris crepitans;* Marshall and Camp, 1995, for *Pseudacris ocularis*) do not prey so heavily on lepidopteran larvae.

Our study is not intended to address the question of whether or not *P. s. illinoensis* feeds underground in nature. However, some if not all of the items consumed were probably consumed at the surface (i.e., Gerridae) because all of the items appeared fresh and the frogs were active at the surface at the time they were killed. However, some of the items such as *Feltia ducens* which shelters underground during the day (Tucker unpublished observations) may be taken after the breeding season in the frog's subterranean haunts.

Fecundity

METHODS: Fecundity was studied by counting oviductal eggs from five DOR females that appeared to retain most of the eggs within the body. Three other DOR gravid females were excluded because most of the eggs were found on the road surface at collection. Eggs were counted under a dissecting microscope at 7X magnification.

We also counted eggs contained in individual egg masses that the female divides her clutch into when ovipositing. Nine such individual egg masses were collected under Illinois Department of Natural Resources permit number 94-8s and were deposited in the collections of the Illinois Natural History Survey. Eggs in these masses were also counted under 7X magnification. Individual eggs in each egg mass were also staged (Gosner, 1960).

RESULTS: We determined an average of 608.2 oviductal eggs present in the clutches of the five females examined. These clutches ranged from 411-783 eggs with a standard deviation of 139.5 eggs. The individual egg masses, collected after oviposition in the field, averaged 21.9 eggs per mass (range = 8-42 eggs, SD = 13.2 eggs). The egg masses themselves ranged from 13 mm long by 7 mm wide for one containing 13 eggs to 18.5 mm long by 5 mm wide in one containing 35 eggs. Average stage for the nine egg masses collected April 13 was stage 5.3 (range = stage 2-stage 7.5, SD = 1.6).

DISCUSSION: Butterfield et al. (1989) provided the most complete description of eggs and egg masses for *Pseudacris streckeri illinoensis* based on Arkansas specimens. They found an average of 468.6 eggs in 12 specimens examined. Females of this subspecies do not lay these eggs in one mass but instead in smaller egg masses. Butterfield et al. (1989) found that 78 individual egg masses averaged 41 eggs each. They also report pre-cleavage ovum size of 2.3 mm. Smith (1961) and Johnson (1987) reported 400 and 200-400 eggs for *P. s. illinoensis*. Trauth et al. (1990) compared reproduction of *P. s. illinoensis* to a small sample from *P. s. streckeri* from Arkansas and found slightly more eggs contained by females of the former.

The mean number of oviductal eggs that we found is somewhat higher than the only other published account that actually reported the extent to which counts varied (i.e., Butterfield et al., 1989). However, both samples are small and variable with Butterfield et al. (1989) reporting a range of 148-1,012 for the 12 specimens they studied. The number of eggs per mass was about half the number reported by Butterfield et al. (1989) but our sample was very small.

Eggs were deposited on grass stems and leaves at the site where we collected the egg masses. Butterfield et al. (1989) also reported that sticks and twigs were used for oviposition. We observed ten pair of amplexing frogs in the process of depositing eggs. All were in a similar posture when first observed. In each case, the female had grasped blades or stems of grass that were oriented parallel to the water's surface. All ten of the females were suspended upside down from this perch so that the egg mass was deposited on the bottom side of the object. These egg masses quickly become obscured by floating silt and debris due to the sticky gelatinous coating holding the egg mass together. Once coated by such material they are difficult to see and the coating may provide some protection from predators.

Post-metamorphic growth

METHODS: The usual methods to study growth such as marking and recapturing individuals and determining the changes in size between captures or procedures such as studying annual rings in bone that require destruction of the animal are difficult to apply to *P. s. illinoensis*. Even toe clipping is difficult because it must be confined to the hind feet. Clipping toes from the front feet could interfere with the use of the hands for forward burrowing (Brown et al., 1972). Because toe clipping can increase mortality in anurans especially where more than one toe is removed per frog (Clarke, 1972; Smith, 1987), only one or at most two toes can be removed. The result is that there are relatively few unique clips available for use in any mark and recapture study of this frog.

Besides that, the fossorial behavior of the frog means that animals can only be marked and recaptured during a short unpredictable time period each year. However, froglets which are relatively easy to capture with drift fences at their natal ponds do disperse to their post-breeding habitat. Since it takes time for the frogs to make such movement, recaptures at various stages of the migration could give an estimate of growth rates during the early post-transformational period of the frog's life (Tucker and Philipp, 1993; Tucker, 1995). This method (see Tucker, 1995, for further details) was used to arrive at an estimate of growth rate for the period immediately after metamorphosis. To arrive at a longer-term growth rate, we compared SVL for recaptured frogs to the mean SVL of froglets without tail stubs marked in 1993 (Tucker and Philipp, 1993; Tucker, 1995).

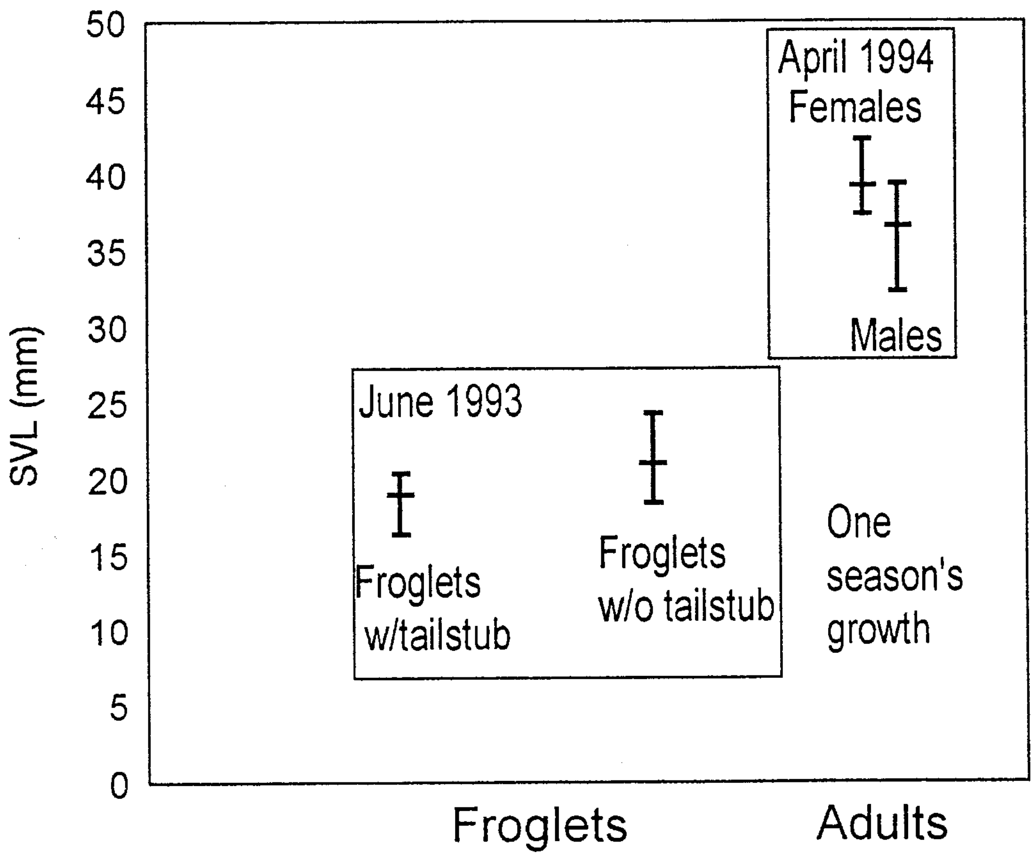
RESULTS: Froglets caught during migration from the natal pond grew at an estimated rate of 1.18 mm/day. Froglets without a tail stub had a mean SVL of 21 mm (SD = 1.21, range = 18-25 mm, n = 506). Twenty frogs marked as newly transforming froglets were recaptured. Seven of the recaptured frogs were females that averaged 39.3 mm in SVL (range = 37-43 mm, SD = 1.98 mm). The remaining 13 were males that averaged 36.8 mm in SVL (range = 32-40 mm, SD = 1.96 mm). Recaptured females had significantly greater SVL than recaptured males (kw = 6.22, p = 0.0127, df = 1). Growth for recaptured females amounted to about 18 mm whereas for recaptured males it was 15.8 mm on average (Fig. 6).

SVL of recaptured females did not differ significantly (kw = 0.30, p = 0.5830, df = 1) from that of 54 other females (SVL = 39.6 mm, range = 33-44 mm, SD = 2.17 mm) that were unmarked when caught. Likewise, SVL of recaptured males did not differ significantly (kw = 2.98, p = 0.0845, df = 1) from that of 71 other males (SVL = 37.8 mm, range = 33-42 mm, SD = 2.0 mm) that were unmarked when caught. SVL for unmarked females is greater than that for unmarked males (kw = 19.28, p = 0.0001, df = 1).

Whether males and females mature at the same rate is unknown. However, the number of females recaptured compared to the number of unmarked females is not statistically different from the number of males recaptured as compared to the number of unmarked males caught (G = 0.48, df = 1, p = 0.4884). This would be consistent with the hypothesis that males and females mature at about the same rate assuming that other factors are equal. Also the sex ratio of the recaptured frogs does not depart significantly from unity as would be expected if males and females matured about the same rate.

Figure 6. Growth in the Illinois chorus frog (*Pseudacris streckeri illinoensis*) from transformation to adulthood.

Figure 6


50
45
40
35
30
25
20
15
10
5
0
SVL (mm)
April 1994
Females
Males
June 1993
Froglets
w/tailstub
Froglets
w/o tailstub
One
season's
growth
Froglets
Adults

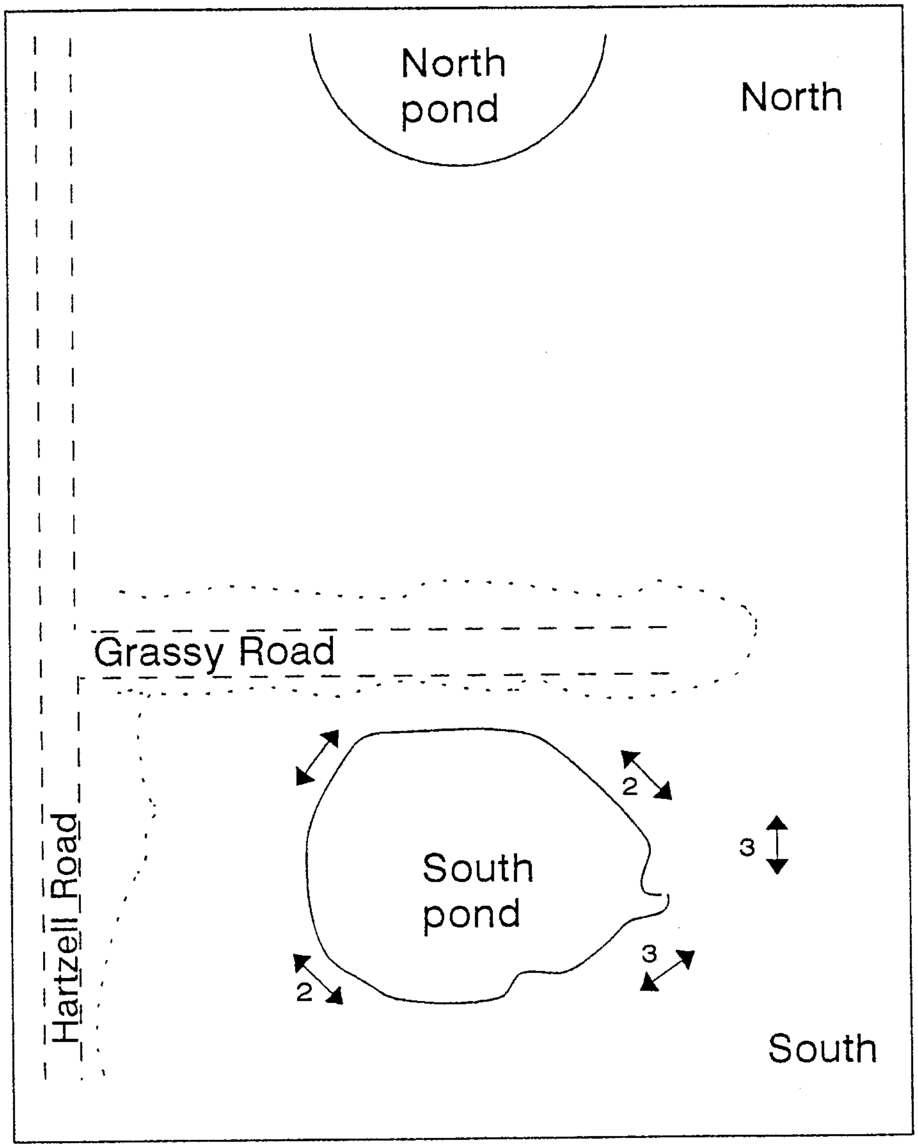
DISCUSSION: Although amphibians may trespass drift fences resulting in sampling bias (Dodd, 1991), this may not be a factor in our study of a fossorial frog. The lowest trespass rates that Dodd (1991) reported from laboratory studies was with *Gastrophryne carolinensis*, another fossorial species.

The froglets observed in 1993 were large relative to the eventual body size of sexually mature males and females (Tucker and Philipp, 1993; Tucker, 1995). The growth rate arrived at suggested that this frog should reach the size of sexually mature frogs in less than a year (Tucker, 1995). Tucker (1995) reported preliminary data on 15 recaptures of frogs marked as froglets in 1993 returning to breed in 1994, thereby confirming the prediction that frogs could mature within a year. Smith (1987) found that *Pseudacris triseriata* that transformed at larger body sizes as compared to smaller conspecifics from the same site also matured within a year. Berven and Gill (1983) made a similar finding for the wood frog (*Rana sylvatica*) but in this case only some of the males matured after one season and the remaining males and the females matured after two seasons.

Whether males and females of *P. s. illinoensis* mature at the same rate is unknown. However, the number of females recaptured compared to the number of unmarked females caught did not differ from the number of males recaptured as compared to the number of unmarked males caught. Also the sex ratio of the recaptured frogs does not depart significantly from unity as would be expected if males and females matured about the same rate. In contrast, the sex ratio of recaptured frogs in *Rana sylvatica* is male biased because most females mature in two years whereas males were able to reach maturity in one year (Berven and Gill, 1983). The preliminary indication that males and females of *P. s. illinoensis* both mature within one year is important because it suggests that our estimates of juvenile survivorship and population size (see above) are less likely to be underestimates. Clearly, our studies are preliminary.

Figure 7. Drift fence placement at the south pond (Brockmeier site) in April 1994 used to capture returning adult frogs.

Figure 7



↔ = drift fence

= number of frogs

Activity patterns

METHODS: We studied activity patterns and their relationships with environmental variables by checking known chorusing sites on the Sand Road study site beginning March 1, 1994. Furthermore, we had placed drift fences at the Brockmeier site on March 15 to detect movement by breeding frogs (Fig. 7). No frog activity was detected until a series of warm rainy nights began on April 9. Once activity was detected on April 9, we surveyed the roads in the Sand Road study site (Sand Road, Streetcar Road, and Hartzell Road = 1 trip) three times each night until April 30 when observations were terminated. The first trip began about 2200, the second at about 2400, and the third at about 0200. We recorded the temperature at the start of each trip as well as rainfall during each trip.

Because the laboratory was fairly close to the study area, we returned there after each trip to mark living frogs and measure (to nearest 1 mm) all frogs. After which we returned to the study site and released living frogs at their point of capture. Vehicle speeds never exceeded 10 km per hour when searching for frogs on the roads. In some areas, we walked the length of the road looking for individuals trapped in a ditch recently dug for a sewer line through the area. Each female found was examined for reproductive status. Gravid females were those for which we could see eggs through the body wall in the groin area. Spent females were those for which we could not see eggs through the body wall.

RESULTS: Frogs were first caught at the drift fences (Fig. 7) and found on roads in the study area on the night of April 9 (Fig. 8) and calling began on April 10. The number of males found on roads and drift fences outnumbered females on the 9th and 10th but females outnumbered males on the next three nights (Fig. 9). Calling was intense from April 10 until April 17 when it ceased except for sporadic calling during a rain event in late April. Except for April 14, the weather was dry between April 12 and 25. Frog movements across roads were again detected when rain fell on the 26th through the 28th.

Figure 8. Distribution of captures during the 1994 breeding season at the Sand Road study site.

Figure 8

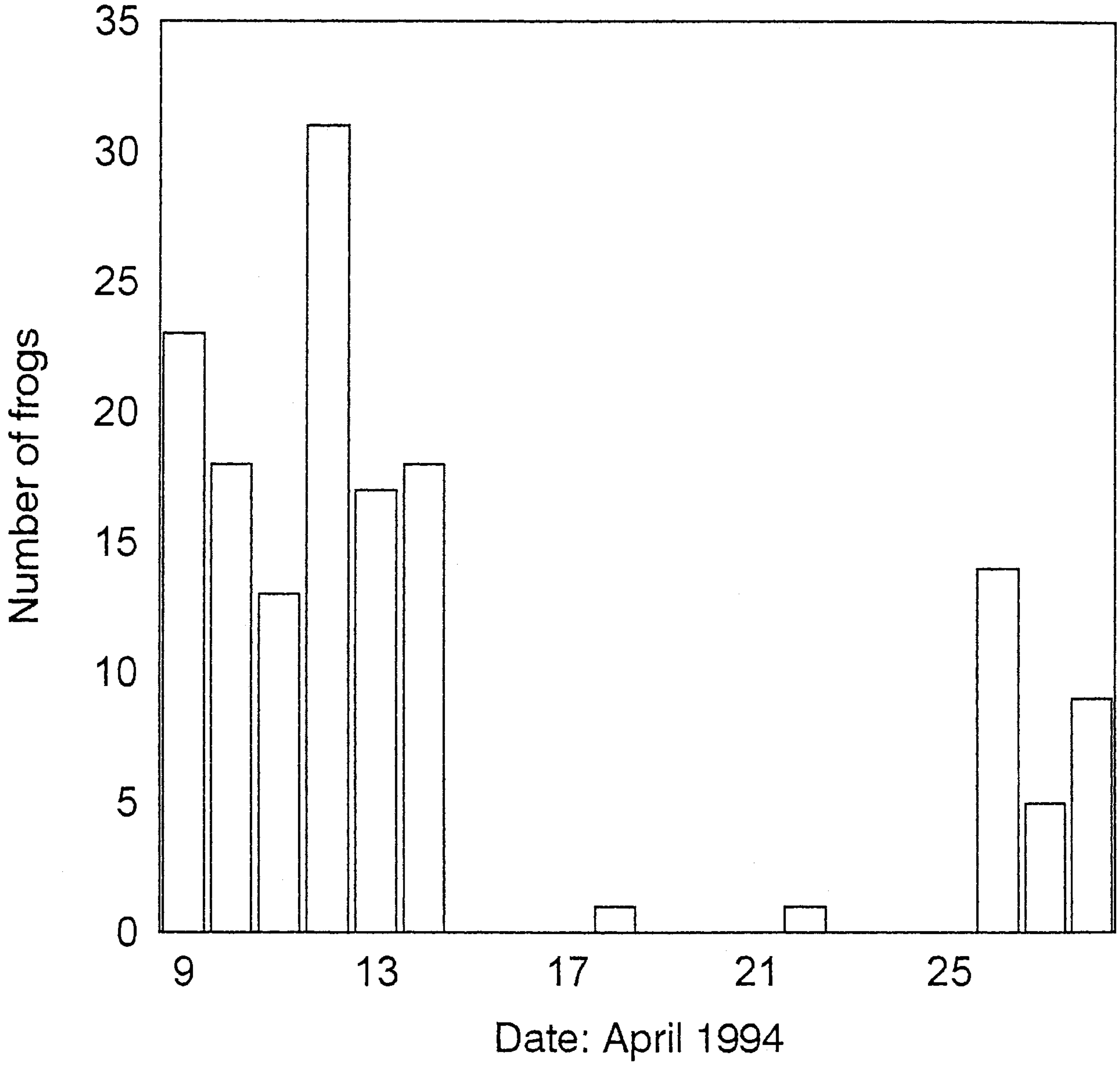
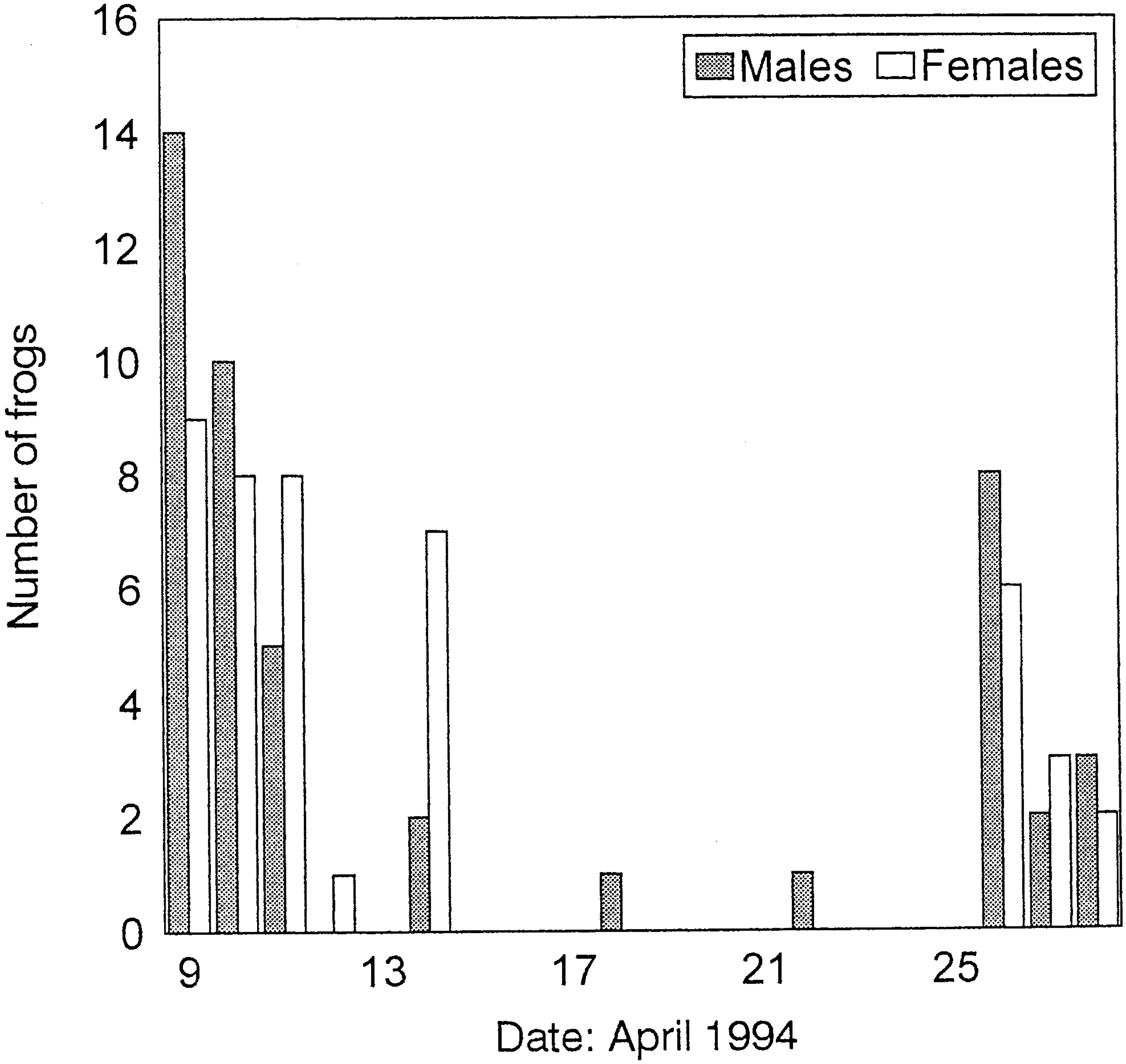


Figure 9. Distribution of captures by sex for the 1994 breeding season excluding frogs taken at choruses.

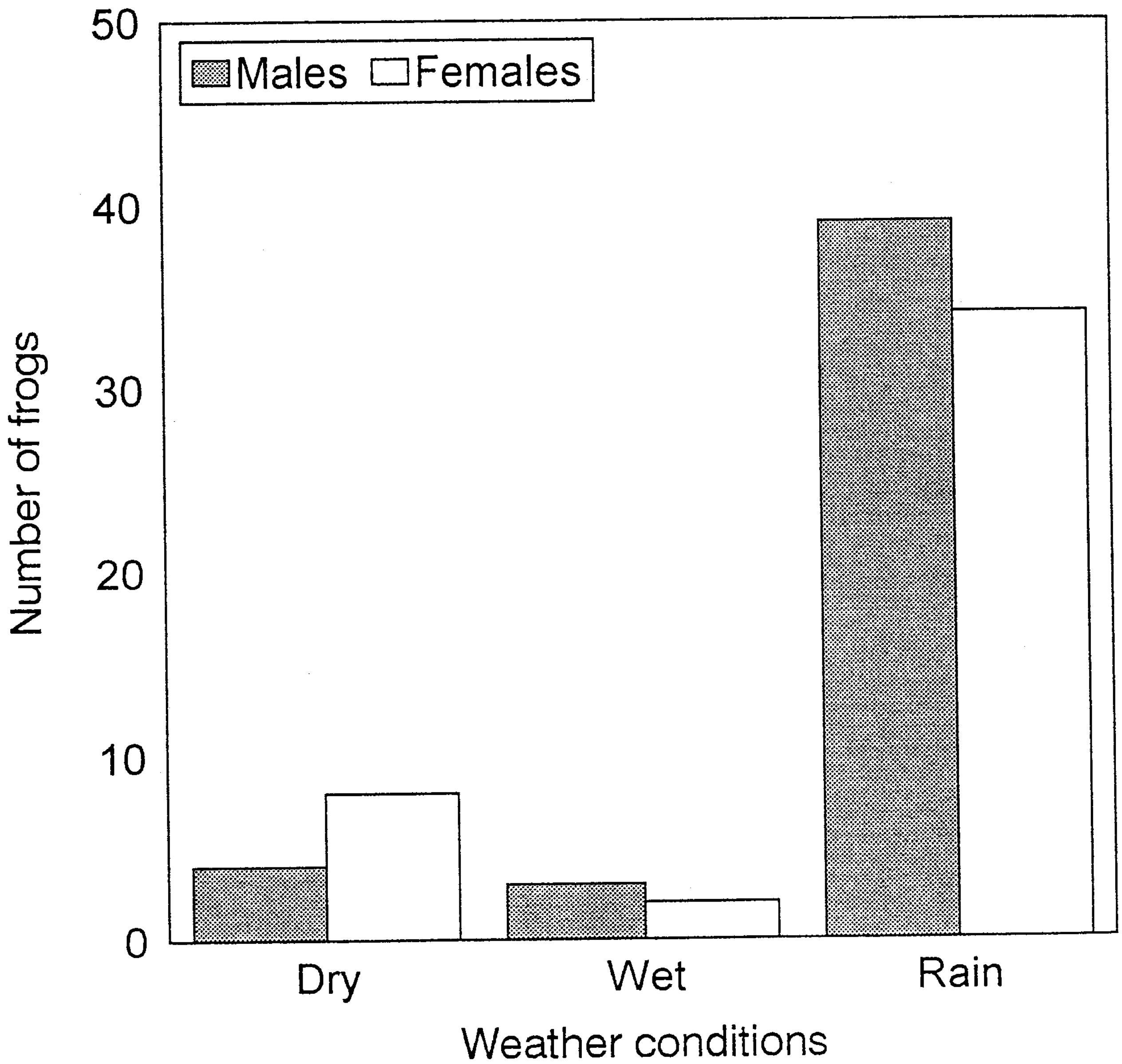
Figure 9



16
14
12
10
8
6
4
2
0
Number of frogs
Males
Females
9
13
17
21
25
Date: April 1994

Figure 10. Distribution of captures by sex for the 1994 breeding season showing the importance of rain to frog movements. Frogs caught at choruses not included.

Figure 10


Males
Females
50
40
30
20
10
0
Number of frogs
Dry
Wet
Rain
Weather conditions

Frog movements at least on roads was highly related to rainfall (Fig. 10, rain). We found few frogs on the roads when rain was not falling (= dry) or even when rain had fallen a short time before the trip (= wet). However, chorusing was not strictly related to rainfall and many frogs were detected at choruses when rain did not fall (Fig. 11).

The short time that breeding occurred in 1994 is strongly suggested by the distribution and reproductive status of females. Gravid females were found moving on roads and at choruses between 9 and 14 April. Spent females were found only on roads, and the first one was found on 12 April (Fig. 12).

We can compare the number of frogs for each trip to temperature (Fig. 13). There is no statistically significant relationship between the two (Spearmans rank correlation coefficient, *rho* = -0.08, $p = 0.7412$).

The relationship between temperature and frog captures can also be examined by trip throughout the duration of the study. Because temperature invariably was lower on the last trip of the night as compared to the first, more frogs should be caught on the first trip than on the second which should produce more than the third if temperature was an important variable in predicting activity of the frog. First trip captures were higher for moving frogs (i.e., those not at choruses) than other trips despite the lack of correlation when data points for each trip were analyzed (Fig. 14). This did not mean that the correlation statistic led to an incorrect conclusion. Frog activity was affected by many variables (i.e., rainfall, above and Fig. 10) which produced considerable variation in the numbers of frogs caught by our methods each night.

Inclusion of captures at choruses (Fig. 15) seemed to further strengthen the argument that temperature is an important determinant of frog activity. However, the pronounced difference between the number of frogs caught at choruses the first trip of the night (Fig. 16) as compared to subsequent ones almost certainly was influenced by disturbance of the chorus by collecting activities. Frogs collected on the first trip obviously would not be available for collection until the third trip of the night. Undoubtedly toe

Figure 11. Distribution of captures by sex for the 1994 breeding season including those caught at choruses.

Figure 11

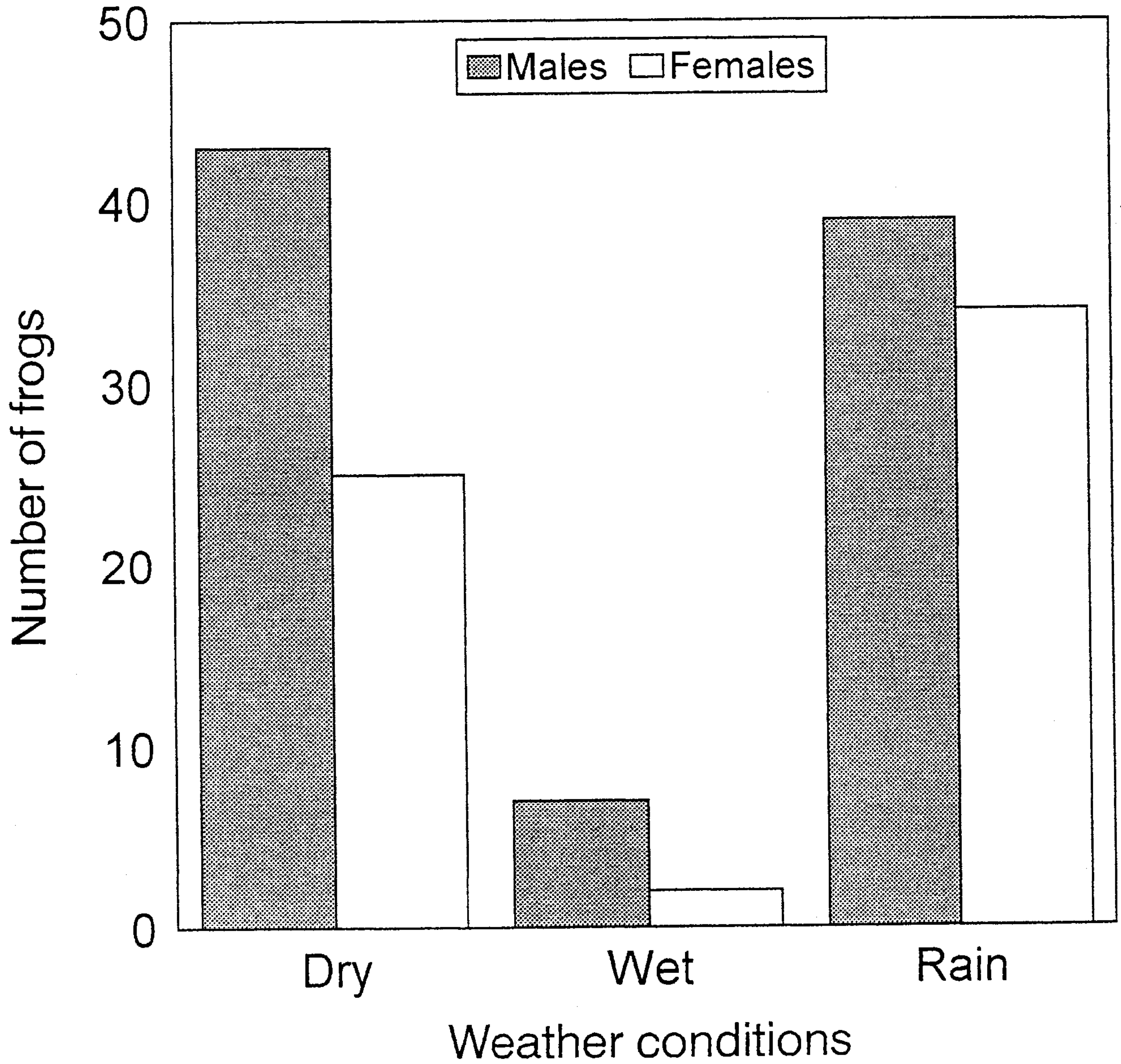
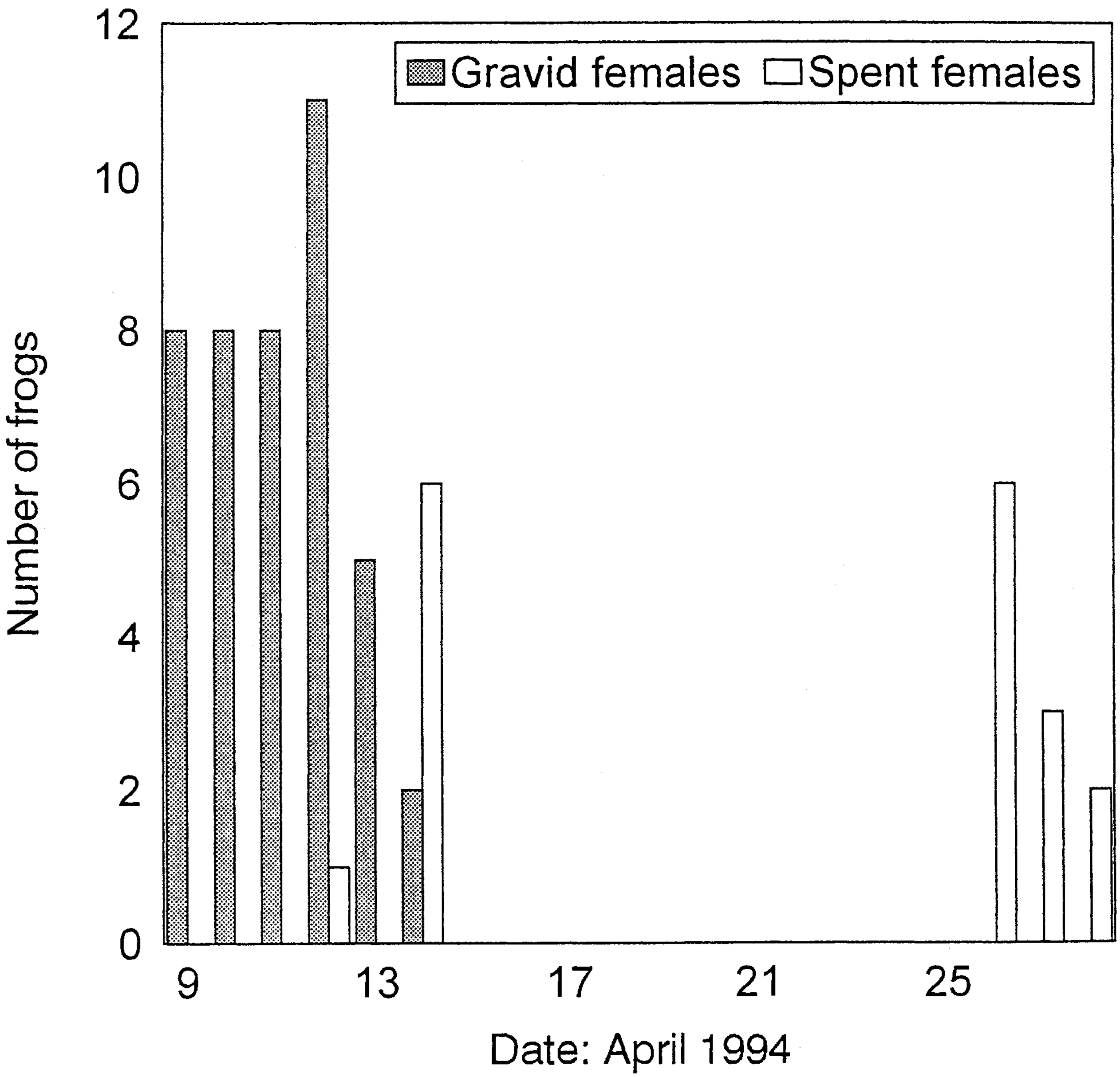

Males
Females
50
40
30
20
10
0
Number of frogs
Dry
Wet
Rain
Weather conditions

Figure 12. Captures of females by reproductive status including those caught at choruses.

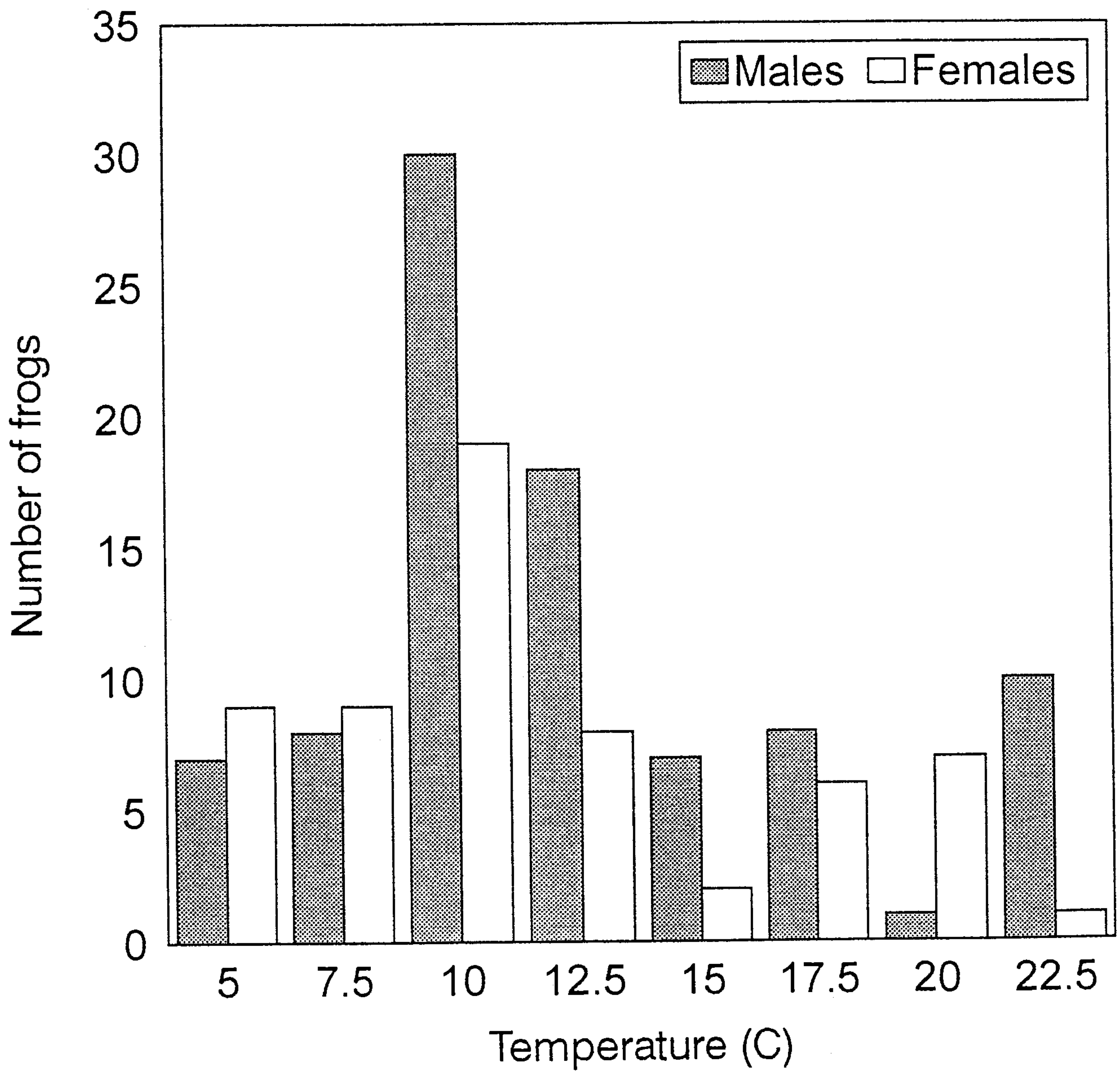
Figure 12



12
10
8
6
4
2
0
Number of frogs
Gravid females
Spent females
9
13
17
21
25
Date: April 1994

Figure 13. Distribution of captures for all frogs by temperature at time of capture.

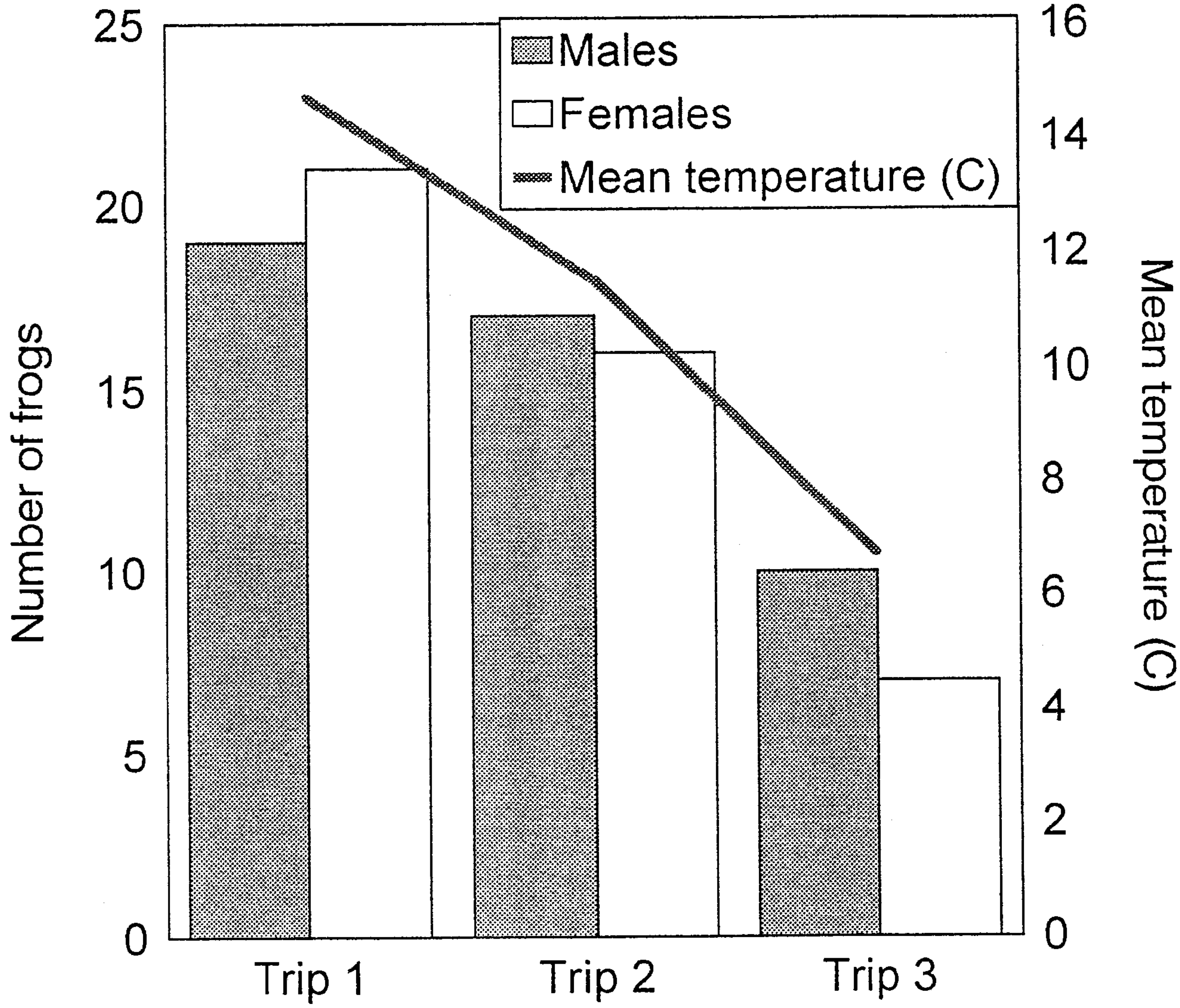
Figure 13



Males
Females
35
30
25
20
15
10
5
0
Number of frogs
5
7.5
10
12.5
15
17.5
20
22.5
Temperature (C)

Figure 14. Captures of males and females by trip excluding those caught at choruses. Only trips where one or more frogs were caught are included.

Figure 14


Males
Females
Mean temperature (C)
Number of frogs
Mean temperature (C)
25
20
15
10
5
0
16
14
12
10
8
6
4
2
0
Trip 1
Trip 2
Trip 3

clipping, capture, and transport were stressful for the frogs and may discourage them from calling again that night once they were released on the second trip of the night.

The number of frogs found by trip for drift fences (Fig. 16) and those found dead on the road (= DOR) or AOR (Fig. 17) were not affected by collector disturbance. Drift fence captures (n = 19) suggested that frogs were most active in the middle of the night, whereas more AOR (n = 48) and DOR frogs (n = 23) were collected on the first trip of the night as compared to the second or third.

DISCUSSION: In all, the 1994 breeding season seems to have been initiated and ended in a six day period between April 9 and 14 as gauged from movement patterns of males and females developed from our intensive collecting protocol. This may not be unusual for *Pseudacris*. Whitaker (1971) reported that most eggs were laid over a short period in any one pond by *P. triseriata*. In one instance, he believed (Whitaker, 1971, p. 142) that all females at a study pond bred in two days. Out of four years where he observed females entering breeding sites, the longest period that females entered the ponds was 5 days and the shortest 2 days.

The suggestion that frog activity is strongly influenced by rainfall is consistent with other studies of anurans (e.g., Bragg, 1960; Duellman, 1995; Stewart, 1995) and our own field experiences. Close correlations with rainfall should be expected in species that depend on ephemeral aquatic habitats for successful reproduction. For *Pseudacris s. illinoensis*, timing of surface movements may be particularly critical as at these times the frogs leave their relatively safe subterranean habitats to enter surface habitats where they are likely exposed to many sources of mortality not encountered by a fossorial frog.

Figure 15. Captures for all male and female frogs by trip.

Figure 15

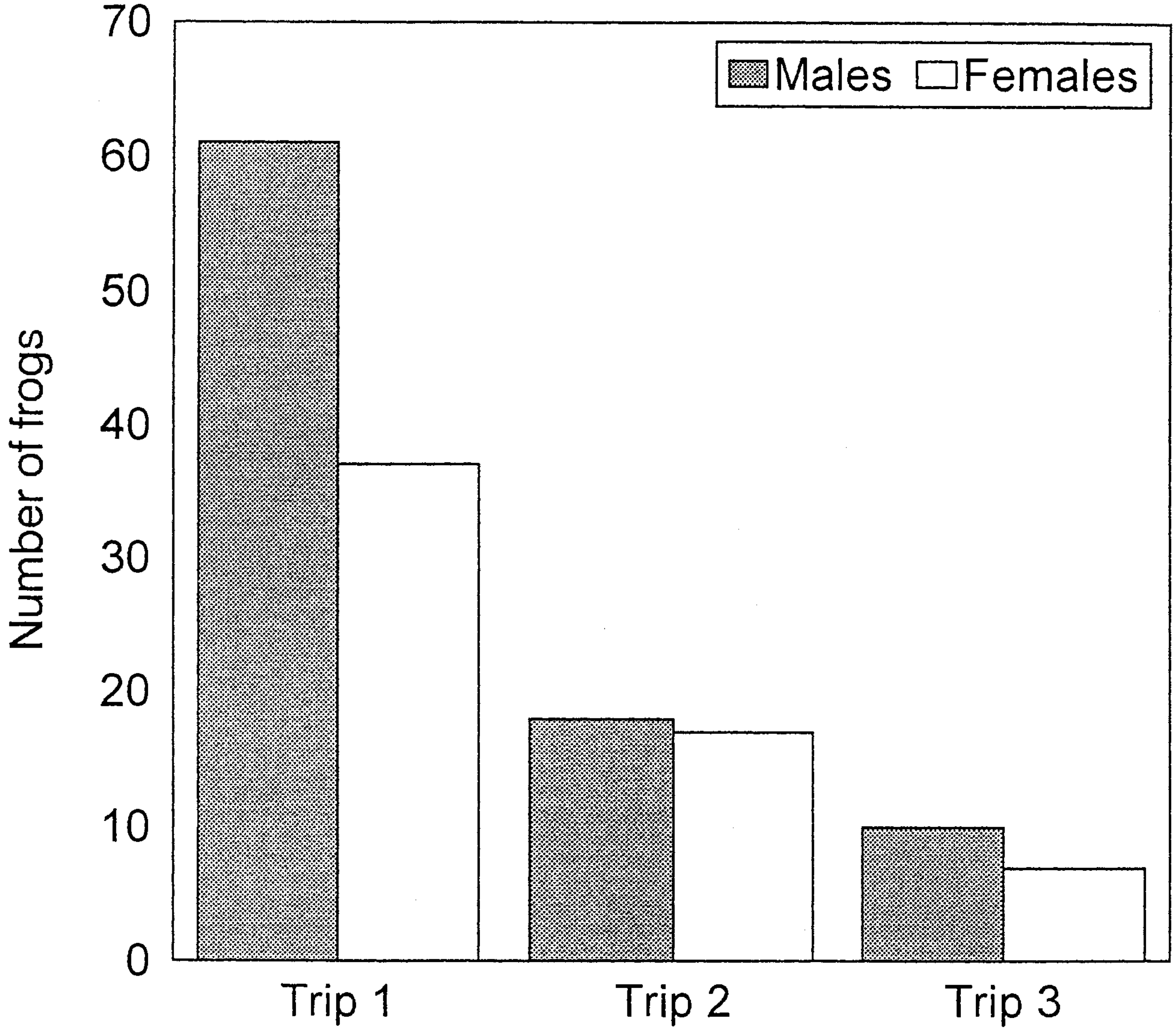
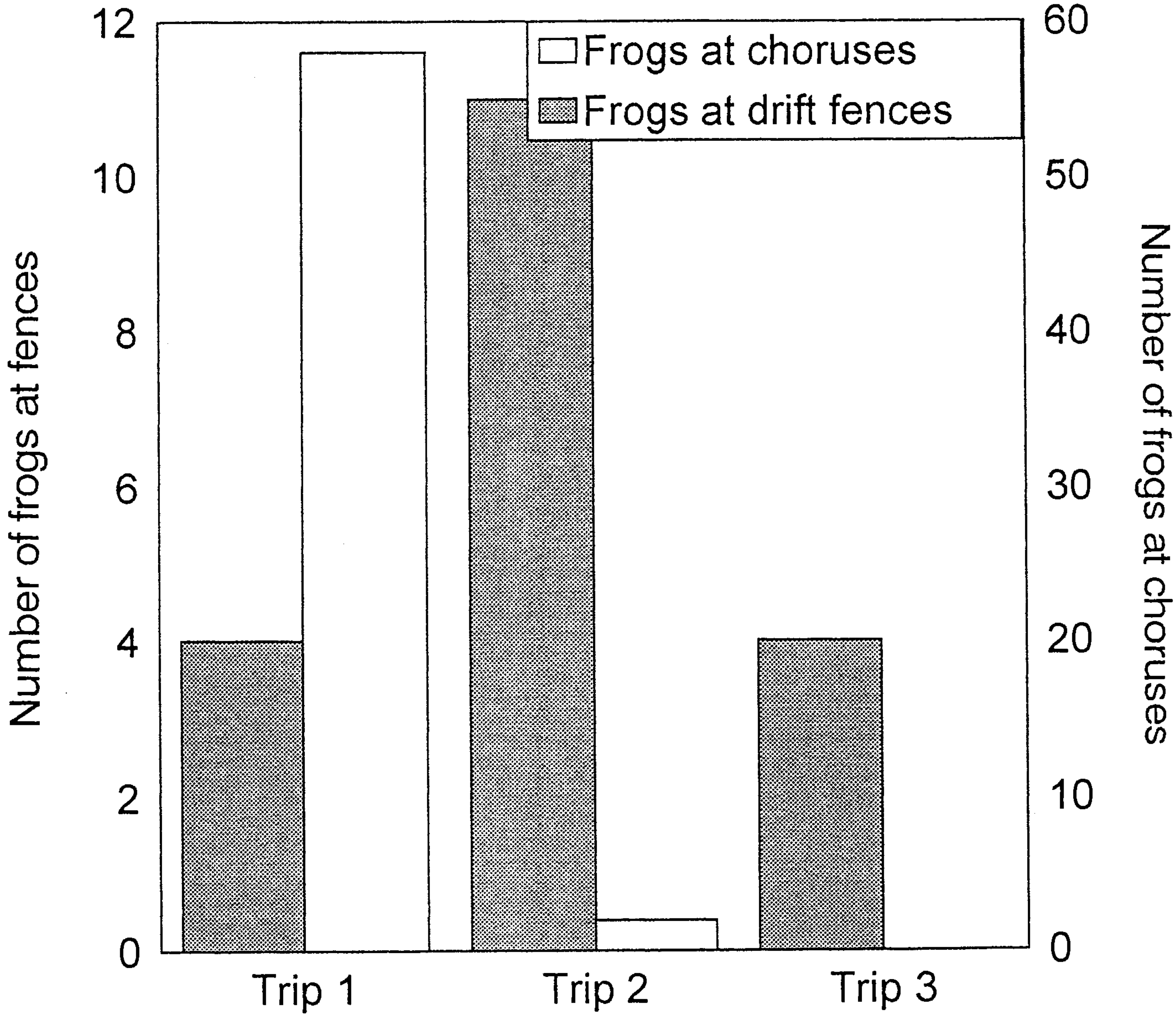

Males
Females
Number of frogs
70
60
50
40
30
20
10
0
Trip 1
Trip 2
Trip 3

Figure 16. Comparison of captures at choruses and on drift fences by trip.

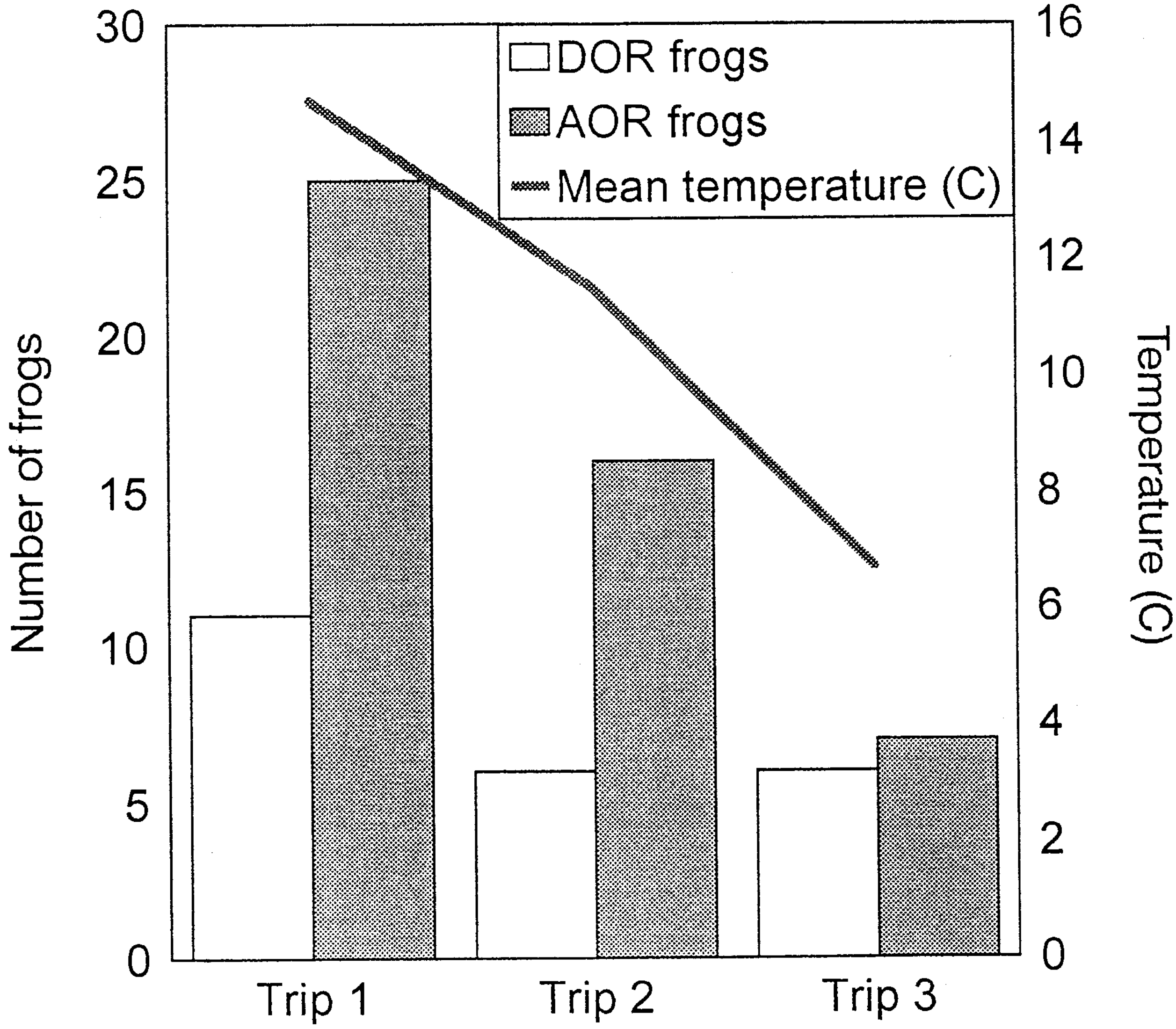
Figure 16



Frogs at choruses
Frogs at drift fences
Number of frogs at fences
Number of frogs at choruses
0
2
4
6
8
10
12
0
10
20
30
40
50
60
Trip 1
Trip 2
Trip 3

Figure 17. Comparison of frogs found alive on road (AOR) and those found dead on road (DOR) by trip.

Figure 17



30
25
20
15
10
5
0
Number of frogs
16
14
12
10
8
6
4
2
0
Temperature (C)
DOR frogs
AOR frogs
Mean temperature (C)
Trip 1
Trip 2
Trip 3

Anthropogenic effects on breeding success

METHODS: During the summer of 1993, the former channel of Cahokia Creek was dammed by slash bulldozed into it by a contractor clearing nearby property. This resulted in general flooding of the Brockmeier site and introduction of fishes into the formerly fishless south pond (Tucker and Philipp, 1993). In effect, the introduction of fishes into a site known to have been used by *P. s. illinoensis* represents an unintentional experiment on the effects of predatory fishes on the breeding habits of the frog similar in many ways to the situation reported by Sexton and Phillips (1986). We therefore surveyed fish late in 1993 and during the spring of 1994 at the Brockmeier site.

We also tracked chorus sites through mid-June in 1994 to determine which of the several sites resulted in successful transformation of tadpoles. Transforming froglets, the best criteria for reproductive success, could not be collected at these sites due to flooding or denial of access by property owners. Therefore, we considered breeding to be successful if two criteria were met. First, we required that tadpoles or eggs of *P. s. illinoensis* be present. Second, at such sites, water must have persisted from April 10 (the initiation of choruses) to mid-June at which time transformation should have occurred (Tucker and Philipp, 1993; Tucker, 1995).

RESULTS: Fishes caught in the summer of 1993 and the early spring of 1994 at the formerly fishless south pond included mosquito fish (*Gambusia affinis*), warmouth (*Lepomus gulosus*), and black bullhead (*Ameiurus melas*). All of these fish averaged less that 50 mm in length during the summer sampling. These same fishes along with golden shiners (*Notemigonus crysoleucas*), the common carp, and tiger salamander larvae were collected in the creek that flooded the pond.

In 1994, *P. s. illinoensis* did not breed in the south pond where they bred in 1993. Adult frogs (n = 19) were caught on the fences (Fig. 7) placed at the pond during April 1994. However, captures were on the west sides of the fences at both ends of the pond (Fig. 7, for instance) suggesting the frogs came to the pond, detected fish (see below), and bypassed it. Choruses occurred in flooded areas to the east and south of the pond. We collected no fish in these ephemeral wetlands (Fig. 1B). Only bullfrogs and toads bred in the south pond in 1994. Like *P. s. illinoensis*, other anurans that used the pond in 1993 bred in the flooded areas to the east and south of the south pond in 1994.

Although, *P. s. illinoensis* did not use the south pond in 1994, the flooded wetlands near to it contained water through mid-June of 1994 so frogs could have successfully transformed from those areas. Tadpoles of both *Pseudacris* species were present in dipnet collections made in May of 1994. However, we could not place drift fences due to flooding in this area and cannot confirm that transformation occurred. Frogs also bred at the Sand Road pit, and water was present at the breeding site until mid-June. We also collected tadpoles of *P. s. illinoensis* at this site in May, 1994. Thus, breeding may have been successful but we could not get access to the property to place drift fences to confirm that transformation occurred.

Twenty-one females were found in amplexus at the greenhouse (Fig. 1B) in a series of low swales in the front lawn and in the ditch bordering Hartzell Road at the greenhouse. Egg masses were found in the ditch by 11 April. Tadpoles of *P. s. illinoensis* were confirmed present on April 20 when dipnetted specimens were positively identified. However, all of these sites had dried by May 10. Consequently, all reproduction in these sites failed in 1994. Considering the small estimated population size (i.e., 420 frogs, see above), this failure could be significant. Assuming a 1 to 1 ratio of males to females, only 210 females were available to breed. Thus, roughly 11% of the population's reproductive effort for 1994 was lost due to drying at this location.

DISCUSSION: Our observations are consistent with previous observations (e.g., Sexton and Phillips, 1986; Kats et al., 1988; Bradford, 1989; Fauth, 1990) that populations of predatory fishes exclude many species of amphibians including *P. s. illinoensis*. Apparently frogs were able to detect the fish in the south pond (i.e., Petranka et al., 1987). Even though fish excluded them breeding still occurred in nearby fishless sites.

While frogs can apparently detect fish, they cannot predict the duration that an ephemerally flooded breeding site will contain water. This is supported by observation made at flooded areas near the greenhouse. In fact, the greenhouse and the ditches acted as a sink (*sensu* Pulliam, 1988) in 1994. The lawn and ditch at this site were flooded by three days of extensive rainfall. Frogs that probably would have used the Brockmeier site, instead stopped at these seemingly ideal ephemeral fishless sites to breed.

Unfortunately for these frogs, the sites are part of the drainage system installed by the human inhabitants and are designed to remove water not retain it. Because the drainage structures were unable to handle the volume generated by the large rain event in April 1994, drainage was slowed sufficiently to tempt the frogs. In 1993, even with record flooding of wetlands and the floodplain, rain was evenly distributed, and drainage in the area was sufficient to prevent water from standing long enough to be used by frogs. In other words, improved drainage in areas of human habitation where drainage is required may actually decrease anthropogenic mortality in frogs such as *P. s. illinoensis* assuming that wetlands where flooding is beneficial and essential to the frogs are not also drained.

Although the event at the greenhouse in 1994 was an isolated one it points out the unpredictable nature of drying in the sorts of ephemeral breeding sites used by this species and the possible magnitude of the effect on an isolated population with few breeding adults. If the survivorship rates determined above are reasonably accurate, then *Pseudacris s. illinoensis* is vulnerable to recruitment failures due to drought much as was found for its congener, *P. ornata* (Pechmann et al., 1991). In that species occupying relatively undisturbed habitat in South Carolina, reduced recruitment and outright failure (three years of the last 6 years studied) resulted in a reduction of the number of breeding females from about 400 to about 125 in eight years of a long-term study (Pechmann et al., 1991). Semlitsch (1987) noted that recruitment failures in short-lived species would severely affect adult population size and could cause local extinction.

Anthropogenic effects (i.e., introduction of fishes to breeding sites and interactions with drainage structures), thus, were an important source of reproductive failure in one instance and effectively altered reproductive behavior with unknown consequences in the other instance. To date all of our results suggest that this frog is a relatively short lived with low juvenile survivorship but rapid growth to maturity. In such species, uninterrupted breeding success is critical to maintenance of populations. Consequently, if this species is to be preserved as part of the Madison County herpetofauna, then actions to reduce anthropogenic causes of reproductive failure are needed. Furthermore, our studies suggest that maintenance of significant amounts of habitat not devoted to agriculture will be required to ensure survival of this frog. If our results are applicable to this frog elsewhere in the range of the subspecies, then the continued existence of the frog in Illinois where almost all available habitat has been converted to agriculture (Brown and Rose, 1988) is threatened.

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Appendix 1:

Preliminary report on use of the Sand Road area by the Illinois chorus frog, *Pseudacris streckeri illinoensis*

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Introduction

At the request of certain interested parties, this report is a summary of observations made during April of 1994. The activity of the Illinois chorus frog (*Pseudacris streckeri illinoensis*) observed in an area along Sand Road in Madison County is reported herein. This area (called Area 2, herein) is being considered for purchase as part of the mitigation for wet land (and chorus frog habitat) loss due to the construction of FAP 310. The purpose of this report is to summarize the possible importance of this site to the Illinois chorus frog in Madison County.

Materials and Methods

The study reported herein is part of a larger study now in its second year. The methods outlined herein refer only to the data presented in this partial summary and not to the entire study. More complete descriptions of the study sites and methods will be presented in the full report on 1994 activities.

Study site. The study site of interest consists of an old borrow pit located along Sand Road (Figs. 1 and 2 [see Fig. 1 of current report]) herein called as Area 2. This site has a sand substrate. Current vegetation coverage is old field in type. The vegetation coverage is patchy with areas of exposed sand present.

Frogs. I captured frogs by road cruising along Sand and Hartzell Roads and by collecting at choruses. Frogs were marked by toe clipping for later recognition. More details of collecting efforts and methods will be presented in the final report.

Results

I located a total of seven choruses in 1994. One of these (Fig. 2 [see Fig. 1 of current report]) occurred on Area 2. This chorus site is a low swale in the southwest central portion of the site. Water persisted through June 6 at this site. Locations of other choruses will be described in the completed report.

I caught a total of eight frogs (1 female and 7 males) at the chorus on the single visit made. However, many more frogs could be heard prior to disturbance of the chorus by collecting efforts. On a subsequent visit, I observed eggs and tadpoles at the chorus site.

I collected 25 further frogs on Sand Road immediately adjacent to the site (Fig. 3 [see Fig. 2 of current report]). I collected 10 other frogs on the curve of Sand Road (= South Curve) close to but not immediately adjacent to the site. I recorded direction of travel for each frog found alive on the road. Movement towards the chorus and away from it occurred indicating that at least some of the frogs observed at the greenhouse could have come from Area 2 (Fig. 2 [Fig. 1 of current report]). Between April 9 and April 26, I collected a total of 43 frogs at or close to this site. Of these, seven individuals had been marked during the 1993 study. These frogs marked as newly transforming froglets were originally captured at the Brockmeier property. The frogs captured at or near Area 2 made up about one-third of all frogs located in 1994.

Discussion

The life cycle of the Illinois chorus frog consists of a breeding phase which occurs in the early to middle spring depending on when the first warm rains of spring occur. This is followed by a prolonged period of post-breeding activity. Post-breeding activity is subterranean in nature with frogs seldom or never coming to the surface during non-breeding seasons.

Because this frog breeds in ephemeral bodies of water that are fishless, it must be able to locate such sites to complete its life cycle. A frog cannot predict how long water will be present in such locations. Therefore, drying of breeding sites prior to metamorphosis can lead to complete or partial loss of reproductive effort. Presence of temporary bodies of water that will persist for at least 90 days is critical to breeding success in this frog.

Although the above summary is brief and simplified, two main requirements for survival of this frog are outlined. First, the frog must have sand substrates for burrowing during non-breeding activities. Second, ephemeral bodies of water that persist long enough to allow transformation of some or all of the tadpoles are required.

Area 2 satisfies both of those requirements. The habitat provides sandy substrates for post-breeding habitat. The location of a shallow and ephemeral pond on the site that persisted into June allowed breeding to occur on the site. Although newly transformed frogs were not observed, they almost certainly successfully transformed at this site in 1994.

The importance of Area 2 can be seen by comparing it to the activity at the Brockmeier and Greenhouse properties where the remaining frogs were found. Frogs at this location consisted of about two-thirds of those captured. Yet all of the choruses on the greenhouse property failed because all breeding sites at the greenhouse dried before tadpoles could transform. Eggs were certainly laid at the greenhouse choruses because they were observed to be present in large numbers. All reproduction at the greenhouse site failed. This may have been as much as one-half the total reproductive effort of the population for 1994. The reproductive efforts at the chorus on the Brockmeier property could not be evaluated directly due extensive flooding. However, some success may have occurred because water at this site persisted into June.

In summary, acquisition of Area 2 will be important in preserving the Illinois chorus frog in Madison County. This would provide a self contained unit that includes both breeding and post-breeding habitat. The importance of protecting habitat is underlined by the distribution of frogs found on the roads in the area. With the exception of two frogs found near the trailer park and two found on the southern portion of Sand Road, all other frogs were found adjacent to old field habitats rather than lawns or agricultural fields. This observation suggests that urban and agricultural development render habitats useless to this frog.

Finally, recaptures of frogs marked in 1993 as newly transforming froglets indicate that frogs will move fairly long distances from their natal ponds. Movements as far as 0.8 km occurred. Area 2 because it is centrally located within the sand body could serve as source area for much of the remaining area in the sand body. Should other areas become suitable for this frogs, Area 2 could serve as a source for new sites.

Only two sites (Area 2 and the Brockmeier property) offer significant expanses of non-agricultural or urban habitats. The latter is not available for sale whereas the former is. Area 2 should be secured as soon as possible.